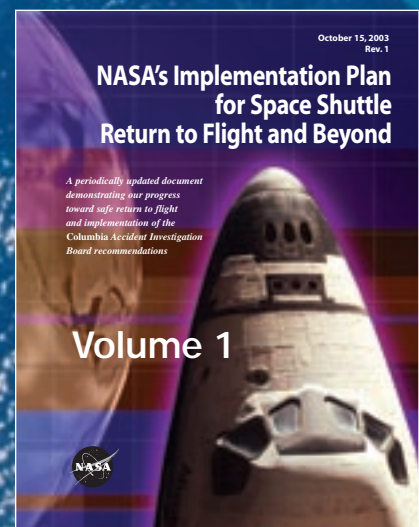


# NASA's Implementation Plan for International Space Station Continuing Flight

*A periodically updated document  
demonstrating our commitment  
to application of the Columbia  
Accident Investigation Board  
recommendations in support  
of safe continuing flight  
of the International Space Station*









# **NASA's Implementation Plan for International Space Station Continuing Flight**

*A periodically updated document  
demonstrating our commitment to  
application of the Columbia Accident  
Investigation Board recommendations in  
support of safe continuing flight of the  
International Space Station*

January 30, 2004  
Revision 1

An electronic version of this implementation plan is  
available at  
<http://www.nasa.gov/news/highlights/returntoflight.html>



# Revision 1 Summary

## January 30, 2004



Revision 1 to *NASA's Implementation Plan for International Space Station Continuing Flight* ("ISS Continuing Flight Plan") reflects our progress to date in responding to the applicable recommendations and observations of the *Columbia* Accident Investigation Board (CAIB), as well as additional ISS Continuous Improvement actions that have been directed by the ISS Program. Revision 1 replaces in its entirety the document initially released on October 28, 2003. Change bars have been added to those pages herein that have been modified since the initial release.

In this revision, NASA responds to the observations contained in Chapter 10 of the CAIB Report, and to the recommendations and observations in Volume II, Appendix D.a, Supplement to the CAIB Report. These responses are included in Parts 2.2 and 2.3, respectively.

NASA's progress from planning to implementation in many critical Shuttle return to flight (RTF) areas is reflected in updates to the Shuttle Program's Volume 1 of NASA's response to the CAIB Report. It includes descriptions of ISS Program participation in assuring adequate on-orbit inspection and repair and contingency crew support capabilities. Concurrently, the ISS has made progress in a number of areas crucial to safe continuing flight operations.

**Safety and Mission Success Week.** The ISS Program actively participated in the Agencywide Safety and Mission Success Week, November 17–21. At each staff meeting and all board and panel meetings during this period, all NASA and contractor employees were encouraged to review the CAIB Report and openly discuss any cultural or technical issues that should be brought to the Program's attention.

**New ISS Utilization/Logistics Flight.** To ensure that we have the logistics necessary to support the ISS crew and continued assembly, NASA has added a flight to the Shuttle manifest. This new flight, STS-121 (ISS flight ULF-1.1), will accomplish some of the ISS utilization and logistics objectives that were removed from STS-114 (ISS flight LF-1). These tasks were deferred to accommodate critical RTF activities such as demonstrating Shuttle Thermal Protection System inspection and repair.

**Organization and Culture.** The NASA Administrator directed the Associate Administrator for Safety and Mission Assurance to develop options for responding to CAIB recommendations 7.5-1, on the establishment of an Independent Technical Authority, and 7.5-2, on safety organization improvements. As part of this effort, NASA is working with industry and the Department of Defense to benchmark their independent oversight processes. The Goddard Space Flight Center Director is leading a complementary team to make recommendations on how the CAIB recommendations and observations can be applied beyond the Shuttle and ISS Programs and across the Agency. The core team for the NASA Engineering and Safety Center is now in place at the NASA Langley Research Center and began operation in November 2003. NASA is also taking a number

of positive steps to identify cultural obstacles to effective risk management, including seeking suggestions from external experts. In this arena of external advice, the Agency has solicited proposals for a comprehensive plan to develop and deploy an organizational culture change initiative within NASA, with an emphasis on safety culture and climate. Using a diversity of inputs, NASA will then make specific and fundamental changes to remove those obstacles with training programs and other management initiatives.

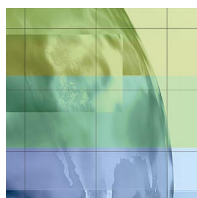
As we issue this revision, NASA is embarking on a new and exciting chapter in space exploration. The President's new vision for U.S. space exploration, "A Renewed Spirit of Discovery," calls for a sustained, achievable, and affordable human and robotic program to explore the solar system and beyond. The ISS has played and will now play an even more crucial role in paving the way for human space exploration beyond low Earth orbit. The President directed NASA to complete assembly of the ISS by the end of this decade and to focus U.S. research and use of the ISS on supporting space exploration goals, with emphasis on understanding how the space environment affects astronaut health and developing countermeasures and spacecraft systems, such as those for life support. Consistent with the recommendations of the CAIB with regard to the Space Shuttle, the President has also directed NASA to separate to the maximum practical extent crew from cargo transportation to the ISS. As a result, we will reexamine crew rotation and ISS logistics and develop a new plan to meet those requirements. Future revisions of *NASA's Implementation Plan for International Space Station Continuing Flight* will reflect the role of the ISS defined in this new vision.

Beyond the CAIB recommendations and observations, ISS continues to receive and evaluate inputs from a variety of sources, including the additional volumes of the CAIB Report released in October 2003, our own employees, our virtual suggestion box at [rtfsuggestions@nasa.gov](mailto:rtfsuggestions@nasa.gov), and a Government Mandatory Inspection Point (GMIP) independent assessment report released in late January 2004. We are systematically assessing the suggested corrective actions and will incorporate these actions into future revisions of our ISS Continuing Flight Plan.



# Contents

<b>Preface .....</b>	<b>vi</b>
<b>Summary .....</b>	<b>ix</b>
<b>Part 1 Response Summaries .....</b>	<b>xi</b>
<b>Part 2 Response Summaries .....</b>	<b>xvi</b>
<b>2.1 ISS Continuous Improvement Actions.....</b>	<b>xvi</b>
<b>2.2 CAIB Observations .....</b>	<b>xx</b>
<b>2.3 CAIB Supplement Recommendations .....</b>	<b>xxiii</b>
<b>Part 1 – ISS’s Response to the <i>Columbia</i> Accident</b>	
<b>Investigation Board’s Recommendations/Observations</b>	
3.2-1 External Tank Thermal Protection System Modifications [RTF] .....	1-1
3.3-2 Orbiter Hardening [RTF].....	1-2
3.3-1 Reinforced Carbon-Carbon Nondestructive Inspection [RTF].....	1-3
6.4-1 Thermal Protection System On-Orbit Inspect and Repair [RTF].....	1-4
3.3-3 Entry with Minor Damage.....	1-7
3.3-4 Reinforced Carbon-Carbon Database.....	1-8
3.3-5 Minimizing Zinc Primer Leaching .....	1-9
3.8-1 Reinforced Carbon-Carbon Spares.....	1-10
3.8-2 Analytical Tools .....	1-12
3.4-1 Ground-Based Imagery [RTF].....	1-14
3.4-2 External Tank Separation Imagery [RTF].....	1-15
3.4-3 On-Vehicle Ascent Imagery [RTF].....	1-16
6.3-2 National Imagery and Mapping Agency Memorandum of Agreement [RTF].....	1-17



# Contents

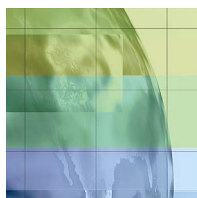
3.6-1	Update Modular Auxiliary Data Systems .....	1-18
4.2-2	Enhance Wiring Inspection Capability .....	1-20
4.2-1	Solid Rocket Booster Bolt Catcher [RTF].....	1-21
4.2-3	Closeout Inspection [RTF] .....	1-22
4.2-4	Micrometeoroid and Orbital Debris Risk .....	1-23
4.2-5	Foreign Object Debris Processes [RTF] .....	1-26
6.2-1	Scheduling [RTF].....	1-28
6.3-1	Mission Management Team Improvements [RTF]...	1-30
7.5-1	Independent Technical Engineering Authority .....	1-32
7.5-2	Safety and Mission Assurance Organization .....	1-32
9.1-1	Detailed Plan for Organizational Changes [RTF].....	1-32
7.5-3	Reorganize Space Shuttle Integration Office.....	1-35
9.2-1	Mid-Life Recertification .....	1-37
10.3-1	Digitize Closeout Photographs [RTF].....	1-38
10.3-2	Engineering Drawing Update.....	1-41

## **Part 2 – International Space Station Continuous Improvement Actions**

### **2.1 – ISS Continuous Improvement Actions**

ISS-1	Waivers, Deviations and Exceptions.....	2-1
ISS-2	Acceptable Risks .....	2-3
ISS-3	Certification of Flight Readiness Process Improvements.....	2-5
ISS-4	Failure Mode and Effects Analyses/Critical Items Lists .....	2-7
ISS-5	Problem Tracking, In-Flight Anomaly Disposition, and Anomaly Resolution.....	2-9
ISS-6	Performance Trending.....	2-18
ISS-7	Hardware and Software Certification Limits.....	2-22
ISS-8	ISS Enhancements.....	2-25
ISS-9	Update Contingency Action Plan .....	2-27
ISS-10	Software Process Improvements.....	2-29
ISS-11	Occupational Safety Reporting .....	2-31
ISS-12	Quality Assurance Improvements .....	2-33
ISS-13	ISS Risk Management.....	2-35





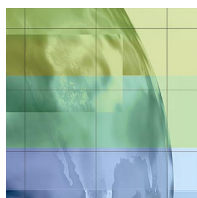
# Contents

## Part 2.2 – Formal Observations of the CAIB

O10.1-1	Public Risk Policy .....	2-39
O10.1-2	Public Overflight Risk Mitigation .....	2-40
O10.1-3	Public Risk During Re-Entry .....	2-40
O10.2-1	Crew Survivability .....	2-42
O10.4-1	KSC Quality Planning Requirements Document .....	2-43
O10.4-2	KSC Mission Assurance Office .....	2-45
O10.4-3	KSC Quality Assurance Personnel Training Programs .....	2-46
O10.4-4	ISO 9000/9001 and the Shuttle .....	2-48
O10.5-1	Review of Work Documents for STS-114 .....	2-49
O10.5-2	Orbiter Processing Improvements .....	2-49
O10.5-3	NASA Oversight Process .....	2-49
O10.6-1	Orbiter Major Maintenance Planning .....	2-51
O10.6-2	Workforce and Infrastructure Requirements .....	2-51
O10.6-3	NASA's Work with the U.S. Air Force .....	2-52
O10.6-4	Orbiter Major Maintenance Intervals .....	2-52
O10.7	Orbiter Corrosion .....	2-53
O10.8	A-286 Bolts .....	2-54
O10.9-1	Hold-Down Post Cable System Redesign .....	2-55
O10.10-1	External Tank Attach Ring .....	2-56
O10.11-1	Shuttle Maintenance Through 2020 .....	2-57
O10.12-1	Agencywide Leadership and Management Training .....	2-58

## Part 2.3 – The “Deal Appendix”

D.a-1	Review Quality Planning Requirements Document Process .....	2-63
D.a-2	Responsive System to update Government Mandatory Inspection Points .....	2-64
D.a-3	Statistically Driven Sampling of Contractor Operations .....	2-65
D.a-4	Forecasting and Filling Personnel Vacancies .....	2-66
D.a-5	Quality Assurance Specialist Job Qualifications ..	2-67



# Contents

D.a-6	Review Mandatory Inspection Document Process .....	2-68
D.a-7	Responsive System to Update Government Mandatory Inspections Points at the Michoud Assembly Facility .....	2-69
D.a-8	Use of ISO 9000/9001 .....	2-70
D.a-9	Orbiter Corrosion.....	2-71
D.a-10	Hold-Down Post Cable Anomaly .....	2-72
D.a-11	Solid Rocket Booster External Tank Attach Ring .....	2-73
D.a-12	Crew Survivability.....	2-74
D.a-13	RSRM Segment Shipping Security .....	2-75
D.a-14	Michoud Assembly Facility Security .....	2-75
D.a-15	Manpower Requirements .....	2-77
D.a-16	Training Programs for Quality Program Personnel.....	2-78
D.a-17	Quality Assurance Specialist Grade Disparity at KSC.....	2-79

**Appendix A – NASA’s ISS Continuing Flight Process**

**Appendix B – ISS Continuing Flight Team Charter Letter**

**Appendix C – Continuing Flight Team Priorities**



# PREFACE

The loss of the Space Shuttle *Columbia* and its crew was devastating for the entire NASA family. For the International Space Station (ISS) Program, finding our way through this tragic loss begins with an unwavering commitment to learn from this tragedy. We will reshape the ISS Program based on those lessons, and carry out the Administrator's directive to continue our mission of building, operating, and performing research on the ISS effectively and safely.

We are committed to those actions that will help return the Shuttle to flight and, in turn, will support our exploration and science objectives. The crew of *Columbia* was dedicated to this vision of science and exploration and devoted their lives to further it. It is our job to continue their vision.

This document details the ISS plans for accepting the findings, complying with the recommendations applicable to ISS, and embracing the *Columbia* Accident Investigation Board (CAIB) Report. The CAIB Report identifies systemic issues that directly or indirectly affect the way we plan, develop, and operate. We will address those CAIB issues and describe how the ISS Program is moving forward on a comprehensive set of process improvements.

This ISS Continuing Flight Implementation Plan captures a snapshot of our review of lessons learned from the *Columbia* accident and how we will work to

implement these lessons into the ISS Program. We will periodically update this document as our review and reassessment of procedures and processes identifies needed changes and technical options for improvements. Updates to this plan will reflect new understanding, increased maturity, and decisions.

Our executive summary provides an overview of the ISS Program's response to the CAIB recommendations and observations and to process improvement actions. Part 1 provides a detailed discussion of activities undertaken by NASA to implement the applicable CAIB recommendations. Part 2.1 discusses additional NASA actions taken as a result of internal reviews and working group recommendations in addition to those made by the CAIB. Part 2.2 contains our responses to applicable CAIB Report observations. Part 2.3 addresses the concerns raised in Appendix D.a of the CAIB Report.

The *Columbia* tragedy serves as strong reminder that space flight is harshly unforgiving of engineering deficiencies, overconfidence, system or human error, and inaccurate risk assessments. The ISS Program's part in the return to flight efforts requires us to continue to identify, understand, control, mitigate, and contain that risk while accomplishing the mission entrusted to us. We do so with the memories of our dear friends and colleagues—the crew of STS-107—serving as both inspiration and an imperative to succeed safely.





## Summary

The *Columbia* Accident Investigation Board (CAIB) addressed both the direct and the contributing causes of the *Columbia* accident and documented its findings in the CAIB Report, Volume I, issued in August 2003, and in Volumes II–VI released in October 2003. The CAIB Report addressed issues that are critical not only for the Space Shuttle Program, but for NASA as a whole. NASA accepts its findings, will comply with the recommendations, and embraces the Report. In addition, NASA is analyzing the CAIB Report for applicability to other programs, including the International Space Station (ISS) Program.

The Space Shuttle Return to Flight Planning Team is focusing on the actions necessary to return the Shuttle safely to flight. ISS Program personnel are participating fully in these important initiatives, and their joint efforts are addressed in Volume 1 of NASA's response to the CAIB Report: *NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond*. In addition, NASA is pursuing an in-depth assessment of its organization with the objective of aggressively implementing corrective actions. NASA chartered the ISS Continuing Flight Team (CFT) to review the CAIB Report and determine the areas that are applicable to the ISS Program and ensure there are actions in place addressing those areas. The purpose of this document—Volume 2 of NASA's response to the CAIB Report: *NASA's Implementation Plan for International Space Station Continuing Flight*—is to document these findings and our progress towards completion of necessary actions.

As with Volume 1, Volume 2 will continue to evolve as our understanding of the activity needed to address each issue matures. We anticipate periodically updating Volume 2 to reflect changes to the plan and progress toward implementing the lessons learned from the CAIB Report as they relate to the ISS Program.

Reaping the lessons learned from the *Columbia* accident and the CAIB's findings started immediately after the accident. While the CAIB was conducting its investigation, the ISS Program began an intensive effort to examine its own processes and operations to reduce risk under a continuous improvement initiative. One of the

objectives was to identify the existence of any risk that has not been reduced to the lowest level and to focus management attention on the residual risks that cannot be eliminated. As the CAIB released its findings, the ISS Program assessed them for applicability. Other continuous improvement activities were derived from the experience the ISS Program has gained from three years of crewed ISS operations and five years of ISS system operation.

### Continuing Flight Team Assessment and Implementation Plan Organization

The CFT assessed every CAIB recommendation and observation for applicability to the ISS. Most of the CAIB recommendations and observations were specific to Space Shuttle design or processes. Others affected NASA safety and engineering processes as a whole. The CAIB Report provides valuable lessons learned applicable to the ISS Program. Part 1 of this volume addresses the CAIB recommendations that were found to be applicable to the ISS. Although some of these recommendations do not specifically apply to the ISS, their underlying intent provides valuable insights that contribute to improving ISS processes. Part 2.1 of this volume addresses many of the ISS Program self-generated areas of continuous improvement. Part 2.2 of this volume addresses the CAIB observations that apply to the ISS. Part 2.3 addresses the additional recommendations and observations found in Appendix D.a.

Where the underlying intent of any CAIB issue is addressed by another recommendation documented in Part 1 or a continuous improvement area or CAIB observation documented in Part 2, the location of the text that addresses the subject will be referenced.

### Reaping the Benefits of the IMCE Assessment

The CAIB Report makes several references to the ISS Management and Cost Evaluation (IMCE) Task Force that conducted an in-depth review of the ISS Program cost, schedule, technical, and management infrastructure. This Task Force was a direct result of the President's fiscal year 2002 (FY2002) Budget Blueprint, which laid groundwork for attaining cost control and regaining ISS



Program credibility needed to fulfill the ISS full potential and international commitments. The Task Force conducted independent assessments of the ISS Program in August and September 2001 and provided 12 recommendations to NASA in an IMCE report released on November 1, 2001. These recommendations provided a roadmap to improve the ISS Program management and cost controls.

In response to the IMCE findings and recommendations, the ISS Program implemented a reliable and effective cost-estimating and management system that provides a structured and disciplined program to manage cost and risks.

### ISS Operations Are Ongoing

The grounding of the Space Shuttle fleet following the loss of *Columbia* had a profound effect on the ISS Program. The loss of capabilities provided by the Space Shuttle resulted in a delay in the assembly of ISS and greatly reduced the cargo mass available for resupply and research. The loss of down mass has impacted our ability to return failed hardware, results of scientific investigations, and environmental samples. In response to these challenges, a plan to allow continued crewed operations of the ISS was developed and agreed to by all ISS Partners. This plan requires the Russian Progress spacecraft be used to supply cargo and crews be rotated with the Russian Soyuz vehicle. This plan is being implemented with the cooperation and efforts of all Partners.

On October 18, 2003, the Expedition 8 crew was launched on a Russian Soyuz vehicle to the ISS. The two-person crew, comprised of Commander Mike Foale and Flight Engineer Alexander Kaleri, is scheduled to spend 192 days on board the ISS, conducting science and maintaining ISS systems. The Expedition 7 crew, Commander Yuri Malenchenko and ISS Science Officer Edward Lu, returned to Earth on October 28, 2003, after spending 185 days on orbit. As a taxi crewmember on the ISS crew exchange, Spanish European Space Agency Astronaut Pedro Duque spent eight days on the ISS performing a variety of experiments. The ISS Program team remains focused on conducting its mission while safely supporting our crew.

### ISS Partnership Is Strong

The ISS International Partnership has stepped up to the challenge of keeping the ISS crewed and operating safely as NASA works through the activities to return the Space Shuttle to flight. Although the grounding of the Space Shuttle has provided a challenge to ISS operations, the spirit of partnership that has built the ISS will sustain it through this difficult period.

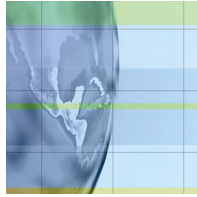
One of the keys to the success of the ISS Program, due to its integrated international nature, has been establishing and maintaining clear communications and coordination among the International Partners and at all levels of the Program structure. As we gain experience in operating the ISS, we realize improvements in communication that lead to an increased effectiveness. The grounding of the Space Shuttle fleet, and the associated constraints on up mass and down mass, has brought further improvements in communication among the Partner teams.

NASA will continue to work closely with its International Partners and keep the lines of communication open as the ISS Program implements process improvements and enhancements as a result of lessons learned from *Columbia*. These changes will be implemented within the framework of our international agreements.

### Conclusion

*NASA's Implementation Plan for International Space Station Continuing Flight* summarizes the results of our review to date of the lessons learned from the loss of *Columbia* and the ISS continuous improvement initiative. It identifies current responsive implementations, outlines technical and management options under consideration to improve the ISS Program and reduce risk, and identifies forward work where solutions are in development.

As ISS continues to fly, the safety of the crew and the vehicle are paramount. As we learn from the loss of *Columbia* and its crew, we must remember that while the Shuttle fleet may be grounded, we still have U.S., Russian, and other International Partner astronauts flying in space. Providing a safe environment for them to conduct research and maintain the ISS is our most critical challenge.



# Response Summaries

## *Part 1 – Responses to the Columbia Accident Investigation Board's Recommendations*

### **Part 1 – Responses to the Columbia Accident Investigation Board's Recommendations**

The following section provides brief summaries of the International Space Station (ISS) Continuing Flight Team's (CFT's) response to each *Columbia* Accident Investigation Board (CAIB) recommendation in the order that they appear in the CAIB Report. Additional detail on each response can be found in the Part 1 and Part 2 sections of this implementation plan. This plan will be periodically updated.

#### **THERMAL PROTECTION SYSTEMS**

##### **R3.2-1 Initiate an aggressive program to eliminate all External Tank Thermal Protection System debris-shedding at the source with particular emphasis on the region where the bipod struts attach to the External Tank. [RTF]**

Although this recommendation addresses threats from loose hardware generated during the launch of the Space Shuttle, the ISS Program recognizes that the safety of the ISS vehicle and other visiting vehicles also depends on avoidance of threats from uncontrolled hardware. ISS is designed to avoid debris generation by the orbital vehicle and visiting vehicles (Soyuz, Progress, Automated Transfer Vehicle, and H-II Transfer Vehicle). In addition, requirements impose limits upon the generation of external contaminants.

Operational steps are taken to preclude threats associated with potential debris sources. Existing risk mitigation measures are in place to control and assess this potential hazard. ISS Program management, design engineers, crewmembers, flight controllers, training instructors, and safety teams continue to provide assurance of this risk mitigation.

##### **R3.3-2 Initiate a program designed to increase the Orbiter's ability to sustain minor debris damage by measures such as improved impact-resistant Reinforced Carbon-Carbon and acreage tiles. This program should de-**

**termine the actual impact resistance of current materials and the effect of likely debris strikes. [RTF]**

The underlying intent of this recommendation is addressed by Part 1, R4.2-2, and Part 2.1, ISS Continuous Improvement Action ISS-8.

##### **R3.3-1 Develop and implement a comprehensive inspection plan to determine the structural integrity of all Reinforced Carbon-Carbon system components. This inspection plan should take advantage of advanced non-destructive inspection technology. [RTF]**

The underlying intent of this recommendation is addressed in Part 1, R4.2-4.

##### **R6.4-1 For missions to the International Space Station, develop a practicable capability to inspect and effect emergency repairs to the widest possible range of damage to the Thermal Protection System, including both tile and Reinforced Carbon-Carbon, taking advantage of the additional capabilities available when near to or docked at the International Space Station.**

**For non-Station missions, develop a comprehensive autonomous (independent of Station) inspection and repair capability to cover the widest possible range of damage scenarios.**

**Accomplish an on-orbit Thermal Protection System inspection, using appropriate assets and capabilities, early in all missions.**

**The ultimate objective should be a fully autonomous capability for all missions to address the possibility that an International Space Station mission fails to achieve the correct orbit, fails to dock successfully, or is damaged during or after docking. [RTF]**

The ISS and Space Shuttle Programs are working together to develop a method to inspect and effect emergency repairs to the Space Shuttle Thermal Protection System. The ISS Program has examined its on-orbit vehicle inspection requirements and implementation details to assess their adequacy. These requirements were found to be inadequate in light of the Space Shuttle fleet grounding. In response to this situation, the ISS Program has developed a systematic approach for performing an exterior imagery survey using on-board assets.

The ISS Program has instituted a plan to periodically perform external surveys of the ISS using on-board assets. The ISS external survey using external cameras is complete. Results indicate that ISS exterior hardware is generally performing as expected and no significant anomalies have yet been revealed. The remainder of the exterior survey, using robotic assets and crew observation, must be completed and analyzed, and results must be reported. It is anticipated that these inspections will be performed by April 2004. The frequency at which the survey is performed has been established based on the survey findings.

**R3.3-3 To the extent possible, increase the Orbiter's ability to successfully re-enter Earth's atmosphere with minor leading edge structural subsystem damage.**

The underlying intent of this recommendation is addressed in Part 1, R4.2-4.

**R3.3-4 In order to understand the true material characteristics of Reinforced Carbon-Carbon components, develop a comprehensive database of flown Reinforced Carbon-Carbon material characteristics by destructive testing and evaluation.**

The underlying intent of this recommendation is addressed in Part 1, R4.2-4.

**R3.3-5 Improve the maintenance of launch pad structures to minimize the leaching of zinc primer onto Reinforced Carbon-Carbon components.**

This recommendation is not applicable to the ISS.

**R3.8-1 Obtain sufficient spare reinforced carbon-carbon panel assemblies and associated support components to ensure that decisions**

**on reinforced carbon-carbon maintenance are made on the basis of component specifications, free of external pressures relating to schedules, costs, or other considerations.**

The ISS has no Reinforced Carbon-Carbon panels; however, there are a number of systems that are required to provide life support and sustain operations. Focusing on the importance of spares to minimize decisions that would be subject to schedule pressure, the ISS Program reviewed its spares provision plans and processes for adequacy. The ISS Program plans and processes were determined to be adequate to support continuing flight operations with crew on board.

The ISS Program reviewed its logistics and maintenance plans to ensure that sparing plans were adjusted for the Shuttle downtime. This process continues as the downtime is extended and critical decisions affecting spares must be made. A spare is currently pre-positioned on orbit for many of these critical orbital replacement units (ORUs). Since the loss of *Columbia*, Progress and Soyuz capacity has limited the ability to deliver limited-life items and large ORUs.

**R3.8-2 Develop, validate, and maintain physics-based computer models to evaluate Thermal Protection System damage from debris impacts. These tools should provide realistic and timely estimates of any impact damage from possible debris from any source that may ultimately impact the Orbiter. Establish impact damage thresholds that trigger responsive corrective action, such as on-orbit inspection and repair, when indicated.**

While the CAIB's recommendation was specific to the debris impacts on a Shuttle, the ISS Program initiated steps to assess all ISS analytical models and tools that are used to support on-orbit operations, anomaly resolution, and decision-making processes. ISS Program boards are reviewing the models to ensure that the model assumptions, limitations, and boundary conditions are understood and are acceptable. The ISS Program boards will address any identified augmentations required as the result of their assessment.

**R3.4-1 Upgrade the imaging system to be capable of providing a minimum of three useful views of the Space Shuttle from liftoff to at least Solid Rocket Booster separation, along any expected ascent azimuth. The operational status of**

**these assets should be included in the Launch Commit Criteria for future launches. Consider using ships or aircraft to provide additional views of the Shuttle during ascent. [RTF]**

The underlying intent of this recommendation is addressed in Part 1, R6.3-2, R6.4-1, and R10.3-1.

**R3.4-2 Provide a capability to obtain and downlink high-resolution images of the External Tank after it separates. [RTF]**

The underlying intent of this recommendation is addressed in Part 1, R6.3-2, R6.4-1, and R10.3-1.

**R3.4-3 Provide a capability to obtain and downlink high-resolution images of the underside of the Orbiter wing leading edge and forward section of both wings' Thermal Protection System. [RTF]**

The underlying intent of this recommendation is addressed in Part 1, R6.3-2, R6.4-1, and R10.3-1.

**R6.3-2 Modify the Memorandum of Agreement with the National Imagery and Mapping Agency (NIMA) to make the imaging of each Shuttle flight while on orbit a standard requirement. [RTF]**

The ISS Program will take advantage of national assets to support on-orbit assessment of the ISS external condition.

NASA concluded a Memorandum of Agreement with the National Geospatial-Intelligence Agency (formerly known as the National Imagery and Mapping Agency) that provides for on-orbit assessment of the condition of each Orbiter vehicle as a standard requirement. NASA has initiated discussions across the inter-agency community to explore the use of appropriate national assets to evaluate the condition of the Orbiter vehicle. In a similar manner, this effort has been applied to the ISS vehicle for ascertaining ISS status, upon request.

Since this action may involve receipt and handling of classified information, the appropriate security safeguards will be observed during its implementation.

**R3.6-1 The Modular Auxiliary Data System instrumentation and sensor suite on each Orbiter should be maintained and updated to include current sensor and data acquisition technologies.**

The ISS Program recognizes that vehicle performance characterization data are required through the life of the vehicle. The ISS depends on telemetry to a greater degree than the Shuttle because the ISS remains continuously in orbit. ISS systems performance assessment instrumentation is combined with operational telemetry requirements to provide a consolidated telemetry capability.

The ISS Program has assessed the vehicle performance characterization instrumentation. Concepts are being evaluated to enhance our ability to characterize the ISS vehicle performance over its lifetime in critical areas, such as structural performance. The implementation of upgrades for increased downlink bandwidth is progressing.

**R3.6-2 The Modular Auxiliary Data System should be redesigned to include engineering performance and vehicle health information and have the ability to be reconfigured during flight in order to allow certain data to be recorded, telemetered, or both as needs change.**

This recommendation is addressed in a consolidated response to Part 1, R3.6-1.

**R4.2-2 As part of the Shuttle Service Life Extension Program and potential 40-year service life, develop a state-of-the-art means to inspect all Orbiter wiring, including that which is inaccessible.**

The nature of the ISS system dictates that physical wiring inspections be performed on orbit. Controls are in place that minimize cable handling and test performance prior to launches. Once operational, the environment that ISS wiring is exposed to is limited to conditions on orbit. Internal wiring is susceptible to damage when it, or hardware nearby, is manipulated through normal daily activity on the ISS. Plans are in place to perform routine wiring inspection of high traffic area wiring as part of normal ISS systems maintenance. External wiring was designed to operate in the micro-meteoroid and orbital debris environment of low Earth orbit.

Even though the ISS elements on orbit have only been in place for five years, the ISS Program will evaluate whether additional routine wiring inspections should be implemented in response to aging concerns. Plans are in place to develop a new test device for internal cable inspections.

**R4.2-1 Test and qualify the flight hardware bolt catchers. [RTF]**

The underlying intent of this recommendation is addressed in Part 2.1, ISS Continuous Improvement Action ISS-12.

**R4.2-3 Require that at least two employees attend all final closeouts and intertank area hand-spraying procedures. [RTF]**

ISS procedures in place for processing of United States hardware have been reviewed and determined to meet the CAIB recommendation for quality control of critical procedures. These guidelines are being formulated into a Standard Practice and Procedure that will apply to all ISS Program hardware processed at Kennedy Space Center (KSC). Documentation to extend the applicability to all ISS Program hardware processed at KSC is scheduled for release in the near future. ISS requires independent closeout of all flight hardware at KSC.

**R4.2-4 Require the Space Shuttle to be operated with the same degree of safety for micrometeoroid and orbital debris as the degree of safety calculated for the International Space Station. Change the micrometeoroid and orbital debris safety criteria from guidelines to requirements.**

Micrometeoroid and orbital debris (MMOD) is recognized as a continuing concern for ISS, Shuttle, and other spacecraft. The ISS was designed for long-term exposure to both micrometeoroids and orbital debris. Robust shielding protection and operational procedures are in place on ISS, or will be implemented during upcoming assembly missions, to reduce the risk of MMOD-induced threats to the crew and vehicle. In addition, ISS hardware is designed to allow MMOD shielding to be augmented over the life of the Program.

**R4.2-5 Kennedy Space Center Quality Assurance and United Space Alliance must return to the straightforward, industry-standard definition of “Foreign Object Debris” and eliminate any**

**alternate or statistically deceptive definitions like “processing debris.” [RTF]**

ISS Program engineers are working with their Shuttle counterparts to review applicable standards and develop a Foreign Object Debris (FOD) Control Plan in response to the CAIB Report. Working closely with Shuttle engineers will ensure a consistent universal approach to minimize the risk of FOD to flight operations and ISS performance.

**R6.2-1 Adopt and maintain a Shuttle flight schedule that is consistent with available resources. Although schedule deadlines are an important management tool, those deadlines must be regularly evaluated to ensure that any additional risk incurred to meet the schedule is recognized, understood, and acceptable. [RTF]**

Our priorities will always be flying safely and accomplishing our missions successfully. We will fly only when the necessary milestones are achieved, and we will not be driven by planning schedules.

The ISS Program has adopted a development and operations schedule that is consistent with available resources; this schedule is necessarily tied to that of the Shuttle. The two Programs’ top-level schedules are integrated and assessed for risk through actions of the Joint (Shuttle-Station) Program Review and Control Board. Furthermore, through the implementation of several ISS Program control processes and tools, technical, cost, and schedule risks and their mitigation plans are assessed regularly. The data are placed in the One NASA Management Information System so that the senior managers in the Space Flight Enterprise can virtually review schedule performance indicators and risk assessments on a real-time basis.

**R6.3-1 Implement an expanded training program in which the Mission Management Team faces potential crew and vehicle safety contingencies beyond launch and ascent. These contingencies should involve potential loss of Shuttle or crew, contain numerous uncertainties and unknowns, and require the Mission Management Team to assemble and interact with support organizations across NASA/Contractor lines and in various locations. [RTF]**



Like the Shuttle Mission Management Team (MMT), the ISS Mission Management Team (IMMT) is responsible for providing programmatic oversight and management direction associated with on-orbit operations of the ISS. In response to CAIB recommendations, the ISS Program has initiated an effort to review and revise the IMMT charter and processes including the adequacy of relevant training plans. In addition, to further ensure that joint MMT/IMMT processes are integrated, the ISS Program is participating with the Space Shuttle Program in the definition of joint simulation cases and will participate fully in all on-orbit training planned for the Space Shuttle MMT.

**R7.5-1 Establish an independent Technical Engineering Authority that is responsible for technical requirements and all waivers to them and will build a disciplined, systematic approach to identifying, analyzing, and controlling hazards throughout the life cycle of the Shuttle System. The independent technical authority does the following as a minimum:**

- Develop and maintain technical standards for all Space Shuttle Program projects and elements
- Be the sole waiver-granting authority for all technical standards
- Conduct trend and risk analysis at the subsystem, system, and enterprise levels
- Own the failure mode, effects analysis, and hazard reporting systems
- Conduct integrated hazard analysis
- Decide what is and is not an anomalous event
- Independently verify launch readiness
- Approve the provisions of the recertification program called for in Recommendation R9.1-1

**The Technical Engineering Authority should be funded directly from NASA Headquarters and should have no connection to or responsibility for schedule or program cost.**

Prior to Space Shuttle return to flight (RTF), as called for in R9.1-1, NASA will develop a comprehensive plan with concrete milestones leading us to a revised organi-

zational structure and improved management practices, and implementing CAIB recommendations 7.5-1 through 7.5-3. The ISS Program is a participant in this process.

NASA is committed to making the organizational changes necessary to respond to the CAIB recommendations 7.5-1 and 7.5-2. The process of implementing and institutionalizing these changes will include investigating funding paths, determining requirement ownership, identifying certification of flight readiness responsibility, and specifying responsibility within NASA's Office of Space Flight for cost, schedule, and technical issues.

The Agency has solicited proposals for a comprehensive plan to develop and deploy an organizational culture change initiative within NASA, with an emphasis on safety culture and climate. Using a diversity of inputs, NASA will then make specific and fundamental changes to remove those obstacles with training programs and other management initiatives.

**R7.5-2 NASA Headquarters Office of Safety and Mission Assurance should have direct line authority over the entire Space Shuttle Program safety organization and should be independently resourced.**

Response to this observation is consolidated in the response to Part 1, R7.5-1.

**R9.1-1 Prepare a detailed plan for defining, establishing, transitioning, and implementing an independent Technical Engineering Authority, independent safety program, and a reorganized Space Shuttle Integration Office as described in R7.5-1, R7.5-2, and R7.5-3. In addition, NASA should submit annual reports to Congress, as part of the budget review process, on its implementation activities. [RTF]**

Response to this observation is consolidated in the response to Part 1, R7.5-1.

**R7.5-3 Reorganize the Space Shuttle Integration Office to make it capable of integrating all elements of the Space Shuttle Program, including the Orbiter.**

The nature of the ISS Program has necessitated a strong focus on Program integration. As the ISS integrator, NASA has led the multilateral definition of integration processes that govern ISS design, development, opera-

tion, and utilization. NASA recognizes that this unique mix of international and organizational cultures and dependencies makes the Program integration function crucial to assuring ISS Program objectives are met, and all issues and anomalies are resolved in a timely manner. Recent contract consolidations, organizational evolutions, and integrated review forms help specifically to address these challenges.

**R9.2-1 Prior to operating the Shuttle beyond 2010, develop and conduct a vehicle recertification at the material, component, subsystem, and system levels. Recertification requirements should be included in the Service Life Extension Program.**

The underlying intent of this recommendation is addressed in Part 2.1, ISS Continuous Improvement Actions ISS-7 and ISS-8.

**R10.3-1 Develop an interim program of closeout photographs for all critical subsystems that differ from engineering drawings. Digitize the closeout photograph system so that images are immediately available for on-orbit troubleshooting. [RTF]**

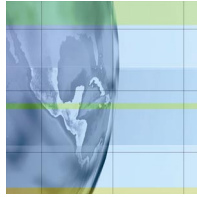
The nature of ISS operations dictates that careful attention is placed on closeout imagery requirements in support of complex assembly operations, as well as remote inspection and maintenance of ISS systems. Images are also used to support systems performance analyses and failure investigation. The ISS Program established requirements to obtain images from hardware as it is built up into assemblies for launch. Lessons learned while operating the ISS for five years have highlighted the importance of closeout imagery and led to strengthening of closeout imagery requirements.

Preflight imagery for International Partner modules being integrated and processed at KSC is acquired per existing requirements. Additionally, ongoing reviews of the preflight imagery plans are performed to assure that all future modules/hardware are fully compliant with ISS Program imagery requirements. On-orbit configuration changes also include imagery closeout requirements and procedures. An existing centralized database is being used and improvements are being implemented. On-orbit digital technology is being pursued to aid in the prompt access to high-quality imagery.

**R10.3-2 Provide adequate resources for a long-term program to upgrade the Shuttle engineering drawing system including:**

- **Reviewing drawings for accuracy**
- **Converting all drawings to a computer-aided drafting system**
- **Incorporating engineering changes**

The ISS Program has directed that careful attention be placed on development, control, and rapid access to engineering data (i.e., drawings). With this in mind, the ISS Program's overall strategy from initiation has been to develop and implement an electronic drawing system. ISS drawings reside in the Vehicle Master Data Base (VMDB). The VMDB has been in operation since 1995. Those portions of the VMDB in .pdf format are currently scheduled to be integrated into a new product data management system called the ISS Electronic Document Management System (EDMS) in early 2004. With this tool, improvement in integration of documents from different sources will be accomplished. While drawings continue to be loaded, audits of the content and process associated with this database are being conducted. These audits will help to identify and resolve deficiencies in data quantity, quality, and user friendliness.



# Response Summaries

## Part 2 – ISS Continuous Improvement Actions and Columbia Accident Board (CAIB) Observations

### Part 2.1 – ISS Continuous Improvement Actions

NASA accepts the *Columbia* Accident Investigation Board (CAIB) findings, will comply with the recommendations, and embraces the Report. We recognize that we must also undertake a fundamental reevaluation of our management culture and processes. To do this, we are participating in the intensive, Agency-wide effort to identify additional actions above and beyond the CAIB recommendations that will further improve the International Space Station (ISS) Program as we continue to mature. The following ISS Continuous Improvement Actions are included here to demonstrate clearly that we are not only evaluating CAIB-recognized issues, but are taking a proactive lead to identify what aspects of our processes and procedures we can do better. To be consistent with Volume 1, the Shuttle Return to Flight Plan, the CAIB observations are included in this Part of Volume 2, the ISS Continuing Flight Plan.

#### **ISS-1 The ISS Program will review all Program waivers, deviations, and exceptions for validity and acceptability.**

The ISS Program has directed all elements to review these exemptions to Program requirements to determine whether the exemption is still valid after five years of on-orbit ISS operational experience. In addition, the ISS Program will evaluate the exemptions to assess whether the totality of exemptions carries additional risk. Particular attention is being placed on those exemptions that carry safety risks of a catastrophic nature with a short time to affect.

NASA will develop a plan to incorporate a periodic review of the waivers, deviations, and exceptions and the associated risk accepted by the Program.

#### **ISS-2 The International Space Station Program will review all hazard report non-compliances, regardless of classification, to review rationale for acceptance of these “accepted risks.”**

The ISS Program has established safety requirements designed to provide the necessary control of hazards. The highest safety risk to the ISS and its crew is represented by a failure to meet ISS safety requirements. For environmental- or operational-induced risks, hazard reports are prepared. When a safety requirement is not met and the ISS Safety Review Panel feels that the risk is adequately controlled, a noncompliance report (NCR) to the hazard report is generated to document the rationale for accepting this risk. As a result of the *Columbia* accident, the ISS Safety Review Panel (SRP) conducted a review of each NCR to determine whether the ISS Program should revisit the associated accepted safety risks. This activity reviewed assumptions and ground rules used when the NCR was accepted to assess whether they were still valid. Many steps were taken to provide a level of confidence on how the original NCRs compare to the current ISS conditions and operations. As appropriate, NCRs will be updated to accurately reflect the risk being accepted by the ISS Program. The highest priority will be addressing those with major impacts followed by those with minor impacts. The SRP will review and concur on each NCR that is revised.

#### **ISS-3 ISS will review its Certification of Flight Readiness (CoFR) process and identify areas for improvement.**

The ISS Program formed a team to assess the adequacy of its Certification of Flight Readiness (CoFR) process and make recommendations for improving the way we review the risks accepted when committing to flight and continued operation of the ISS. This assessment included a process review, a documentation review, and an audit of the key processes used by certifying organizations in making their endorsement decisions. ISS Program management reviewed the initial recommendations in September 2003 and implemented many recommendations to improve the conduct of Soyuz Stage Operations Readiness and Flight Readiness Reviews.

This process was successfully executed during the ISS Flight 7S (7<sup>th</sup> Soyuz) Stage Operations Readiness Review (SORR) as all Program elements fully discussed concerns surrounding the ISS environmental monitoring capability. When concerns with the adequacy of ISS environmental monitoring were brought to the SORR, these concerns were openly discussed and actions were

put in place to ensure that all possible steps to mitigate the risk were implemented. The concerns and mitigating actions were fully discussed subsequently at the Flight Readiness Review (FRR), where NASA management decided to proceed with the launch of the Expedition 8 crew. Furthermore, the ISS Program continues to track the status of each mitigating action that was accepted at the FRR.

**ISS-4 The ISS Program has initiated a review of its critical items list (CIL) and the failure modes and effects analyses (FMEAs) associated with the CIL to revalidate acceptance rationale based on experience gained in operating a crewed ISS for almost 3 years.**

The ISS Program is revalidating all ISS critical items along with their FMEAs. All ISS critical items were reviewed by the ISS Reliability and Maintainability (R&M) Panel, with the support of ISS Safety and Mission Assurance (S&MA).

**ISS-5 Review ISS anomaly resolution processes to ensure that proper requirements are in place and anomaly resolution processes are operating effectively.**

The ISS Program evaluated the current ISS anomaly investigation and resolution requirements to determine their adequacy to support final assembly and long-term sustaining engineering of the ISS. The review resulted in several recommended actions to improve the anomaly resolution process and to ensure consistency in anomaly resolution and anomaly documentation as well as to provide ISS management useful methods by which to assess and track anomalies. Many of these recommended actions have been implemented. An action schedule has been developed and presented to ISS Program management to capture the remaining recommendations.

**ISS-6 Review ISS system performance trending requirements and implementation status and make recommendations for improvement.**

The monitoring of trends in the performance of the ISS is becoming increasingly important as the time of operation of its subsystems increases and its overall complexity grows. The grounding of the Shuttle fleet and potential effects on ISS resupply has heightened concern in this area. The ISS Program undertook the performance trending continuous improvement action to improve its capabilities and processes in acquiring, tracking, managing, reporting, reviewing, and using performance trending

data in support of ISS planning, decision-making, and risk management.

Improvements in these areas are expected to facilitate the ISS Program's ability to detect and respond to trends or recurring events that could otherwise lead to an eventual failure or catastrophic occurrence without intervention. Performance trend data are also used for supportability planning in areas such as logistics, spare provisioning, reliability predictions, and resource management. These data can additionally be applied to help establish launch and increment readiness, and to support decisions in mission support and anomaly resolution. Performance trending is also considered to be essential for risk assessment and risk management.

**ISS-7 The ISS Program will assess its ground and on-orbit hardware to verify that they are within hardware qualification and certification limits, in light of the grounding of the Space Shuttle fleet. Where life limits are approaching, take appropriate action.**

Some ISS hardware now awaiting launch at the Kennedy Space Center (KSC) have a limited shelf life, such as the electrical power system batteries and solar array wings. A limited set of hardware on orbit is designed for periodic replacement and, therefore, carries certification limits that affect its useful life. With the grounding of the Space Shuttle fleet, the ISS Program has systematically reviewed hardware certification limits and taken the necessary actions.

The ISS Program has established on-ground preventative maintenance requirements for spare hardware that is still on the ground and is not integrated into larger elements. However, no on-ground preventative maintenance requirements exist for hardware once integrated into larger elements, such as the truss sections. Launch delays due to the *Columbia* accident have driven the ISS Program to assess and define the preventative maintenance requirements for integrated hardware waiting for launch. The ISS Program is taking action to meet these requirements to gain the confidence that integrated hardware will function as required when assembled on ISS.

Within weeks of the accident, all on-orbit hardware with certification limits was reviewed. Where additional testing or analyses could be done to extend these certification limits, this testing and analysis was approved and performed. Where this was not possible, strategies and justifications were developed to allow continued use of these items in an acceptable manner.

**ISS-8 Review lessons learned from ISS operations and identify any enhancements to ISS hardware or software that significantly mitigate risk to crew safety and mission success. Survey ISS system teams to identify any further modifications to hardware or software that reduce risk.**

Enhancements to the ISS design are defined as changes that are over and above those which are required to meet ISS Program requirements, which significantly mitigate risk to crew safety or mission success. The ISS Program conducted a bottom-up review of potential enhancements and selected several for implementation. At the completion of the ISS enhancements review, the total list of suggested improvements has been collected and will serve as an input to the ISS Planned Product Performance Improvements (P<sup>3</sup>I) process.

**ISS-9 Review program, project, and supporting organization contingency action plans and update them based on *Columbia* mishap lessons learned.**

The ISS Program performed an extensive review of the ISS Contingency Action Plan (CAP) during the March–July 2003 time frame to reflect the lessons learned from the *Columbia* mishap and to convert the original Johnson Space Center (JSC)-ISS Lead Center Plan to an ISS Program CAP. As a result of this activity, the ISS Program Manager approved the ISS Program CAP on July 29, 2003. NASA periodically reviews the ISS CAP and conducts contingency simulations to ensure that key personnel are familiar with the CAP. An effort to review International Partner actions during execution of the CAP will soon begin.

**ISS-10 The ISS Program’s avionics and software management organization will continue to evolve software development and integration processes to provide high fidelity flight software suites with higher productivity. In addition, ISS software uplink and long term sustaining processes will be updated to reflect lessons learned from on-going ISS software upgrade activities.**

The ISS has initiated an effort to improve its software development processes. The Software Engineering Institute’s (SEI’s) Capability Maturity Model (CMM) is being used as the “measuring stick” by which to document the maturity of each developer’s processes. The ISS prime contractor development sites have the industry norm CMM rating of Level 3 or higher. The

ISS software development effort is seeking to achieve a Level 5 assessment.

To date, over 1.25 million source lines of code have been developed and flown with minimal problems. Lessons learned from software upgrades on orbit are continually applied to improving software management processes.

**ISS-11 The International Space Station (ISS) has implemented some initiatives to facilitate the reporting of occupational and on-orbit safety concerns by its employees.**

The ISS Program has implemented an approach to increase ISS Program employee awareness of established NASA safety reporting systems. The goal is to ensure that employees are encouraged to report any safety concerns, as well as to ensure that employees are aware of the NASA Safety Reporting System program availability. The ISS Program will continue to make personnel aware of the methods available to report safety concerns, as well as to modify the communication methods as improvements are identified.

The ISS Program actively participated in the Agencywide Safety and Mission Success (SMS) Week, November 17–21, 2003. At each staff meeting and all board and panel meetings during this period, all NASA and contractor employees were encouraged to review the CAIB Report and openly discuss any cultural or technical issues that should be brought to the Program’s attention. The ISS-specific results of the SMS Week are currently being assessed.

**ISS-12 The ISS Program has initiated action to make recommendations for improvements in quality assurance aspects of ISS development and operations.**

The mission of ISS Program quality assurance (QA) is to ensure that the ISS Program maintains the necessary discipline in adhering to requirements and executing processes, thus contributing to overall technical excellence and the safety of the ISS vehicle and crew.

To accomplish these goals, high-quality processes must be established and effective QA activities must be in place. The ISS Program has identified the need to strengthen the QA role in management and implementation of its anomaly resolution processes and is undertaking specific action to satisfy this need.

**ISS-13 The ISS Program will assess its process for tracking Top Program Risks via the existing**



**ISS risk management tool, specifically the Integrated Risk Management Application, and recommend improvements where necessary.**

The ISS Program is reviewing all accepted, mitigated, and closed risks in the safety, quality, and reliability areas to determine where significant risks have been accepted and whether these items should be reexamined further, or should be defined as Top Program Risks and brought into the existing ISS continuous risk management process for increased visibility.

In terms of the ISS management of previously closed risks, the Space Station Program Control Board has approved a plan for a near-term reassessment and for periodic future reviews of closed Top Program Risks.

## **Part 2.2 – CAIB Observations**

The observations contained in Chapter 10 of the CAIB Report expand upon the CAIB recommendations, touching on the critical areas of public safety, crew escape, vehicle aging and maintenance, QA, test equipment, and the need for a robust training program for NASA managers. NASA is committed to examining these observations and has already made significant progress in determining appropriate corrective measures. The following CAIB observations are considered applicable to the ISS.

### **Public Safety**

#### **O10.1-1 NASA should develop and implement a public risk acceptability policy for launch and re-entry of space vehicles and unmanned aircraft.**

ISS is participating in the development of a NASA public risk policy so that ISS end-of-life considerations are included. A working group is currently defining standards, requirements, risk criteria, and a risk management process. A NASA Procedures and Guidelines document is nearing completion that will include risk acceptance policy. When the document is approved, the ISS Program will seek the appropriate formal agreements with the ISS Partners.

#### **O10.1-2 NASA should develop and implement a plan to mitigate the risk that Shuttle flights pose to the general public.**

#### **O10.1-3 NASA should study the debris recovered from *Columbia* to facilitate realistic**

**estimates of the risk to the public during Orbiter re-entry.**

Responses to observations O10.1-2 and O10.1-3 are summarized as follows:

NASA's approach to the risks posed by Space Shuttle flights, which are closely integrated with the ISS Program, are addressed by the Space Shuttle Return to Flight Plan. The ISS is designed to enter the atmosphere only at its end of life through a controlled entry. Return of ISS visiting vehicles is similarly controlled with respect to public risk. ISS end-of-life disposal is covered in the Environmental Impact Statement for ISS and in specific requirements in the U.S. Orbital Segment's specifications. To assure controlled vehicle disposal, propellant reserves are managed to assure the delivery of adequate impulse to control entry into one of the six predefined impact zones. The *Mir* disposal in 2001 presented the ISS Program with, in effect, a dress rehearsal for ISS disposal.

NASA maintains a proficient team of trajectory specialists, who work both Shuttle and ISS and ISS visiting vehicles to maintain constant surveillance of ISS attitude and altitude for planned and unplanned entries.

### **Crew Escape and Survival**

#### **O10.2-1 Future crewed-vehicle requirements should incorporate the knowledge gained from the *Challenger* and *Columbia* accidents in assessing the feasibility of vehicles that could ensure crew survival even if the vehicle is destroyed.**

The primary corollary for this crew survivability observation is to ensure that any crewmember on board the ISS has an effective escape route to the ground. ISS crewmembers always have a Soyuz vehicle available to them should the ISS vehicle become incapacitated. The ISS implications of Shuttle contingency support are addressed jointly by the ISS and Space Shuttle Programs as described in the *NASA Implementation Plan for Space Shuttle Return to Flight and Beyond*, Section SSP-3. NASA's long-term efforts to develop new crewed vehicles build upon the lessons learned from previous and contemporary U.S. and Russian spacecraft. Documented safety requirements are contained in NASA Procedures and Guidelines document (NPG) 8705.2, Human Rating Requirements and Guidelines, recently updated with ISS assistance. In addition, more detailed

requirements for ISS crew and cargo transportation have been provided to developers of new vehicles.

## **Industrial Safety and Quality Assurance**

**O10.4-1 Perform an independently led, bottom-up review of the Kennedy Space Center Quality Planning Requirements Document to address the entire quality assurance program and its administration. This review should include development of a responsive system to add or delete government mandatory inspections.**

The ISS Program designates inspection points that must be verified by QA personnel during hardware fabrication, build-up, test, etc. The ISS/Payload Processing Safety and Mission Assurance (SMA) organization established and maintains NASA's Quality Planning Requirements Document (QPRD) for the ISS. An audit/assessment of KSC's ISS quality process and technical implementation is in progress. The NASA and contractor QPRDs will be updated to require annual reviews.

**O10.4-2 Kennedy Space Center's quality assurance programs should be consolidated under one Mission Assurance office, which reports to the Center Director.**

The CAIB noted that QA at KSC requires several improvements, including the organizational structure. KSC has formed a team comprised of personnel from each directorate with SMA organizations to consolidate the SMA organizations at KSC, including the ISS. KSC will consolidate all SMA efforts into a centralized SMA organization reporting to the Center Director.

ISS Program management is also strengthening the Quality Assurance process as described in Part 2.1, ISS Continuous Improvement Action ISS-12.

**O10.4-3 Kennedy Space Center quality assurance management must work with NASA and perhaps the Department of Defense to develop training programs for its personnel.**

NASA will improve the observed deficiencies in basic QA philosophy by developing a training program comparable to the Defense Contract Management Agency (DCMA), using existing training programs where possible. A joint KSC-ISS and Shuttle Quality Assurance Training Team is developing a new process for training new and current training programs for QA personnel.

**O10.4-4 Kennedy Space Center should examine which areas of International Organization for Standardization 9000/9001 truly apply to a 20-year old research and development system like the Space Shuttle.**

NASA, along with a team of industry experts, will evaluate the applicability of ISO 9000/9001 to United Space Alliance KSC operations. This evaluation will lead to a recommendation for future use of the standards or changes to surveillance or evaluations of the contractors.

## **Maintenance Documentation**

**O10.5-1 Quality and Engineering review of work documents for STS-114 should be accomplished using statistical sampling to ensure that a representative sample is evaluated and adequate feedback is communicated to resolve documentation problems.**

**O10.5-2 NASA should implement United Space Alliance's suggestions for process improvement, which recommend including a statistical sampling of all future paperwork to identify recurring problems and implement corrective actions.**

**O10.5-3 NASA needs an oversight process to statistically sample the work performed and documented by [United Space] Alliance technicians to ensure process control, compliance, and consistency.**

Responses to observations O10.5-1, O10.5-2, and O10.5-3 are summarized as follows:

The CAIB observed the need for improvements in how NASA performs statistical sampling of documentation and of performed work. Noting that contractor work at KSC is fundamentally different between the Shuttle and ISS Programs, the ISS Program performed a review and systemic analysis of STS-114 work documents for payloads ground processing (STS-114 being the next Shuttle flight to the ISS). Proven statistical sampling methods were used. The STS-114 review led to relatively minor recommendations, none that would affect the technical integrity of the processed payloads. Teams were formed to determine the root cause and long-term corrective actions of those discrepancies found. These recommendations were assigned Corrective Action Requests that will be used to track the implementation and effectiveness of

the corrective actions. Improvements in contractor surveillance and training of Quality personnel is ongoing.

### **Orbiter Maintenance Down Period/Orbiter Major Modification**

**O10.6-1** The Space Shuttle Program Office must make every effort to achieve greater stability, consistency, and predictability in Orbiter major modification planning, scheduling, and work standards (particularly in the number of modifications). Endless changes create unnecessary turmoil and can adversely impact quality and safety.

**O10.6-2** NASA and United Space Alliance managers must understand workforce and infrastructure requirements, match them against capabilities, and take actions to avoid exceeding thresholds.

The underlying intent of observations O10.6-1 and O10.6-2 is addressed in Part 1, R6.2-1.

**O10.6-3** NASA should continue to work with the U.S. Air Force, particularly in areas of program management that deal with aging systems, service life extension, planning and scheduling, workforce management, training, and quality assurance.

**O10.6-4** The Space Shuttle Program Office must determine how it will effectively meet the challenges of inspecting and maintaining an aging Orbiter fleet before lengthening Orbiter major maintenance intervals.

Responses to observations O10.6-3 and O10.6-4 are summarized as follows:

The ISS Program addresses vehicle aging through its design, verification, operation, and maintenance activities. Experience with the Russian *Mir* space station during ISS Phase 1 also proved to be invaluable and directly relevant to ISS performance assurance. The ISS Program will also participate with the Shuttle Program in reviews with other agencies regarding vehicle aging.

### **Orbiter Corrosion**

**O10.7-1** Additional and recurring evaluation of corrosion damage should include non-destructive analysis of the potential impacts on structural integrity.

**O10.7-2** Long-term corrosion detection should be a funding priority.

**O10.7-3** Develop non-destructive evaluation inspections to find hidden corrosion.

**O10.7-4** Inspection requirements for corrosion due to environmental exposure should first establish corrosion rates for Orbiter-specific environments, materials, and structural configurations. Consider applying Air Force corrosion prevention programs to the Orbiter.

Responses to observations O10.7-1 through O10.7-4 are summarized as follows:

The ISS Program addresses corrosion prevention through its design, verification, operations, and maintenance programs. The flight crew, for example, regularly inspects behind structures to look for hidden moisture pockets that might cause corrosion problems in the future. Also operational experience with the air-conditioning systems is being gained to determine whether further ground and/or on-orbit practices are required.

### **Brittle Fracture of A-286 Bolts**

**O10.8-1** Teflon (material) and Molybdenum Disulfide (lubricant) should not be used in the carrier panel bolt assembly.

**O10.8-2** Galvanic coupling between aluminum and steel alloys must be mitigated.

**O10.8-3** The use of Room Temperature Vulcanizing 560 and Koropon should be reviewed.

**O10.8-4** Assuring the continued presence of compressive stresses in A-286 bolts should be part of their acceptance and qualification procedures.

The ISS Program continues to assess these observations for potential hazards.

## Hold-Down Post Cable Anomaly

**O10.9-1 NASA should consider a redesign of the system, such as adding a cross-strapping cable, or conduct advanced testing for intermittent failure.**

The ISS applicability of this observation in terms of pyrotechnic devices is under review.

## Solid Rocket Booster External Tank Attachment Ring

**O10.10-1 NASA should reinstate a safety factor of 1.4 for the Attachment Rings—which invalidates the use of ring serial numbers 16 and 15 in their present state—and replace all deficient material in the Attachment Rings.**

Although the ISS does not use this specific hardware, a variety of analysis and testing methods are used to assure that appropriate factors of safety are maintained and any deviations are well understood with corresponding risk mitigation measures. The underlying intent of this observation is covered in other ISS Continuous Improvement actions.

## Test Equipment Upgrades

**O10.11-1 Assess NASA and contractor equipment to determine if an upgrade will provide the reliability and accuracy needed to maintain the Shuttle through 2020. Plan an aggressive certification program for replaced items so that new equipment can be put into operation as soon as possible.**

The Shuttle and ISS Programs have initiated an assessment of all critical Program equipment and will continue to assess such equipment through the use of a health assessment process and annual supportability reviews. ISS electronic ground equipment, ground systems, and simulators already use digital technology. Obsolescence upgrades and simulator upgrades have been budgeted. ISS maintenance and calibration of existing equipment are managed to ensure readiness for use on flight hardware.

ISS regularly reviews equipment status and identifies where upgrades are needed to support the checkout and maintenance of the ISS modules and elements.

## Leadership/Managerial Training

**O10.12-1 NASA should implement an Agency-wide strategy for leadership and management training that provides a more consistent and integrated approach to career development. This strategy should identify the management and leadership skills, abilities, and experiences required for each level of advancement. NASA should continue to expand its leadership development partnerships with the Department of Defense and other external organizations.**

The ISS Program recognizes the need for an improved career development program to provide trained managers for the future. The ISS Program is in the process of developing an education/training curricula similar in concept to military programs that prepare officers for increasingly advanced positions of leadership. Also, key personnel are identified for accelerated development and may attend a variety of governmental and non-governmental opportunities to enhance management and leadership potential.

## Part 2.3 – CAIB Supplement Recommendations; Response to Volume II, Appendix D.a, Supplement to the Report

Volume II, Appendix D.a, also known as the “Deal Appendix,” supplements the CAIB Report. This appendix outlines concerns raised by Brigadier General Duane Deal and others that, if addressed, might prevent a future accident from occurring. Some of the 14 recommendations and three observations contained in this appendix have been previously addressed and, therefore, our response to those recommendations refers to the location in the Plan where our previously provided response is found. The appendix recommendation and observation numbers were added by NASA for tracking purposes.

## Quality Assurance

**D.a-1 Perform an independently led, bottom-up review of the Kennedy Space Center Quality Planning Requirements Document to address the entire quality assurance program and its administration. This review should include development of a responsive system to add or delete government mandatory inspections. Suggested Government Mandatory Inspec-**

**tion Point (GMIP) additions should be treated by higher review levels as justifying why they should not be added, versus making the lower levels justify why they should be added. Any GMIPs suggested for removal need concurrence of those in the chain of approval, including responsible engineers.**  
[Recommendation]

This recommendation is addressed in Part 2.2, O10.4-1. The ISS Program Quality Assurance Office at Johnson Space Center (JSC) will perform an independent audit of the KSC ISS quality processes, including an assessment of the NASA QPRD, to determine the effectiveness of the Government Mandatory Inspection Point (GMIP) criteria. The NASA QPRD and the contractor's QPRD are being updated to require annual reviews and to document feedback and appeals procedures for GMIP change initiators.

**D.a-2 Kennedy Space Center must develop and institutionalize a responsive bottom-up system to add to or subtract from Government Inspections in the future, starting with an annual Quality Planning Requirements Document review to ensure the program reflects the evolving nature of the Shuttle system and mission flow changes. At a minimum, this process should document and consider equally inputs from engineering, technicians, inspectors, analysts, contractors, and Problem Reporting and Corrective Action to adapt the following year's program.** [Recommendation]

This recommendation is addressed in Part 2.2, O10.4-1. The ISS Program Quality Assurance Office at JSC will perform an independent audit of the KSC ISS quality processes, including an assessment of the NASA QPRD, to determine the effectiveness of the GMIP criteria. The NASA QPRD and the contractor's QPRD are being updated to require annual reviews and to document feedback and appeals procedures for GMIP change initiators.

**D.a-3 NASA Safety and Mission Assurance should establish a process inspection program to provide a valid evaluation of contractor daily operations, while in process, using statistically-driven sampling. Inspections should include all aspects of production, including training records, worker certification, etc.,**

**as well as Foreign Object Damage prevention. NASA should also add all process inspection findings to its tracking programs.**  
[Recommendation]

The underlying intent of this recommendation is addressed in the combined response to Part 2.2, O10.5. The foreign object debris aspects of this are addressed in our response to CAIB recommendation R4.2-5 in Part 1. The status of evaluations of contractor training records and worker certification will be reported in a future edition of this document. For ISS cargo processing, NASA uses the Checkout, Assembly, and Payload Processing Services (CAPPS) contract surveillance plan while evaluating improvements that could impact the overall surveillance strategy. NASA and the CAPPS contractor will sample and analyze work documents and ensure corrective and preventative action is accomplished for noted discrepancies.

**D.a-4 The Kennedy quality program must emphasize forecasting and filling personnel vacancies with qualified candidates to help reduce overtime and allow inspectors to accomplish their position description requirements (i.e., more than the inspectors performing government inspections only, to include expanding into completing surveillance inspections).** [Recommendation]

KSC is currently centralizing the SMA workforce to meet CAIB observation O10.4-2. As a part of that process, workforce staffing requirements, personnel qualifications, and position descriptions will be assessed. As a specific improvement example beyond the current reliance upon permanent staff and new staff developed through a cooperative education program, KSC has been hiring temporary and term-limited appointment employees to alleviate short-term staffing issues.

**D.a-5 Job qualifications for new quality program hires must spell out criteria for applicants, and must be closely screened to ensure the selected applicants have backgrounds that ensure that NASA can conduct the most professional and thorough inspections possible.** [Recommendation]

NASA, by law, rule, and regulation, must use the qualifications standards published by the U.S. Office of Personnel Management (OPM) for the GS-1910 QA Specialist in assessing the qualification of applicants. In addition, selecting officials can identify particular crit-



ical selection criteria to assess candidates to ensure they are getting fully qualified individuals.

**D.a-6 Marshall Space Flight Center should perform an independently-led bottom-up review of the Michoud Quality Planning Requirements Document (QPRD) to address the quality program and its administration. This review should include development of a responsive system to add or delete government mandatory inspections. Suggested Government Mandatory Inspection Point (GMIP) additions should be treated by higher review levels as justifying why they should not be added, versus making the lower levels justify why they should be added. Any GMIPs suggested for removal should need concurrence of those in the chain of approval, including responsible engineers. [Recommendation]**

The underlying intent of this recommendation is addressed in Part 2.2, O10.4-1. The ISS Program Quality Assurance Office at JSC will perform an independent audit of the KSC ISS quality processes, including an assessment of the NASA QPRD, to determine the effectiveness of the GMIP criteria. The NASA QPRD and the contractor's QPRD are being updated to require annual reviews and to document feedback and appeals procedures for GMIP change initiators.

**D.a-7 Michoud should develop and institutionalize a responsive bottom-up system to add to or subtract from Government Inspections in the future, starting with an annual Quality Planning Requirements Document review to ensure the program reflects the evolving nature of the Shuttle system and mission flow changes. Defense Contract Management Agency manpower at Michoud should be refined as an outcome of the QPRD review. [Recommendation]**

The underlying intent of this recommendation is addressed in Part 2.2, O10.4-1. The ISS Program Quality Assurance Office at JSC will perform an independent audit of the KSC ISS quality processes, including an assessment of the NASA QPRD, to determine the effectiveness of the GMIP criteria. The NASA QPRD and the contractor's QPRD are being updated to require annual reviews and to document

feedback and appeals procedures for GMIP change initiators.

**D.a-8 Kennedy Space Center should examine which areas of ISO 9000/9001 truly apply to a 20-year-old research and development system like the Space Shuttle. Note: This item is currently Observation O10.4-4 in the Board report; however to avoid further diluting the quality program focus, it is urged this become a Recommendation. [Recommendation]**

This recommendation is addressed in Part 2.2, O10.4-4. Beyond the additional QA requirements imposed in 2002 at KSC, the ISS Program will address the applicability of any changes to its ISO 9000/9001 processes that are identified by ongoing Agency and Space Shuttle reviews.

## **Orbiter Corrosion**

**D.a-9 Develop non-destructive evaluation inspections to detect and, as necessary, correct hidden corrosion. [Recommendation]**

The underlying intent of this recommendation is addressed in Part 2.2, O10.7-1 through O10.7-4. The ISS Program addresses corrosion surveillance through its design and verification processes for prelaunch hardware and through operations and maintenance procedures for on-orbit hardware. Improvement insights from expertise outside the ISS Program will be considered.

## **Hold-Down Post Cable Anomaly**

**D.a-10 NASA should evaluate a redesign of the Hold-Down Post Cable, such as adding a cross-strapping cable or utilizing a laser initiator, and consider advanced testing to prevent intermittent failure. [Recommendation]**

As noted in Part 2.2, O10.9-1, the ISS applicability of this recommendation regarding pyrotechnic devices is under review.

## **Solid Rocket Booster External Tank Attach Ring**

**D.a-11 NASA must reinstate a safety factor of 1.4 for the Attach Rings – which invalidates the use of ring serial numbers 15 and 16 in their present state – and replace all deficient**

**material in the Attach Rings.  
[Recommendation]**

The underlying intent of this recommendation is addressed in Part 2.1, ISS Continuous Improvement Actions 1, 2, 3, 4, 7, and 12. While the ISS Program does not use this specific hardware, it does manage and verify the design and operational margins of the hardware components to ensure that specified safety margins are maintained.

## **Crew Survivability**

**D.a-12 To enhance the likelihood of crew survivability, NASA must evaluate the feasibility of improvements to protect the crew cabin of existing Orbiters. [Recommendation]**

The underlying intent of this recommendation is addressed in Part 2.2, O10.2-1.

ISS capabilities to ensure crew survivability are extensive and are derived from lessons learned during all crewed space vehicles to date, including those of our Russian partners.

## **RSRM Segments Shipping Security**

**D.a-13 NASA and ATK Thiokol perform a thorough security assessment of the RSRM segment security, from manufacturing to delivery to Kennedy Space Center, identifying vulnerabilities and identifying remedies for such vulnerabilities. [Recommendation]**

## **Michoud Assembly Facility Security**

**D.a-14 NASA and Lockheed Martin complete an assessment of the Michoud Assembly Facility security, focusing on items to eliminate vulnerabilities in its current stance. [Recommendation]**

Recommendations D.a-13 and D.a-14 are addressed together for ISS purposes. In response to homeland security issues prior to CAIB, NASA/KSC initiated improvements to security control procedures and facilities at the Center and specifically at those facilities where Shuttle and ISS hardware is processed. The ISS Program is reassessing its security at other locations, and will discuss results in a future edition of this document.

**D.a-15 As an outcome of the Quality Program Requirements Document review, manpower refinements may be warranted. While Board recommendations to evaluate quality requirements documents should drive decisions on additional staffing, in the interim, staffing with qualified people to current civil service position allocations should be expedited. [Observation]**

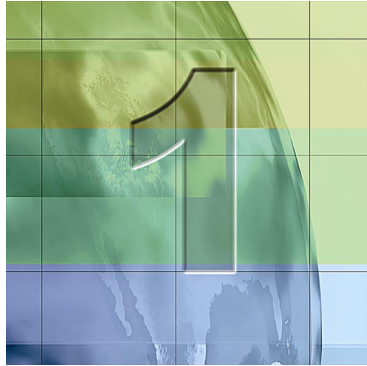
As addressed in Part 2.2, O10.4-2, KSC is currently centralizing the SMA workforce, establishing new resource requirements and staffing levels to meet CAIB recommendations. In addition, KSC is hiring temporary and term-limited appointment employees to alleviate short-term staffing issues.

**D.a-16 NASA-wide quality assurance management must work with the rest of NASA (and perhaps with the Department of Defense) to develop training programs for its quality program personnel. [Observation]**

This observation is addressed in Part 2.2, O10.4-3. A team was formed to develop and document an improved training program based on Department of Defense and DCMA training requirements.

**D.a-17 An evaluation of the disparity of Quality Assurance Specialist civilian grades at Kennedy Space Center compared to other NASA centers should be accomplished to determine whether the current grade levels are appropriate. [Observation]**

A comparative study of civil service positions, functions, and grades across all NASA centers has been accomplished that shows that KSC does not have a pay grade disparity for ISS QA Specialists or ISS Mission Assurance Managers.

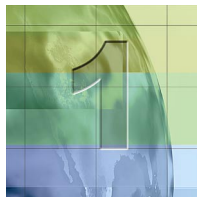


## Part 1

# The International Space Station's Response to the *Columbia* Accident Investigation Board's Recommendations

*The following section details NASA's response to each applicable CAIB recommendation in the order that it appears in the CAIB report. This is a preliminary plan that will be updated as further actions are identified and completed. We will also update this document to include responses to the CAIB observations and other CAIB Report Volumes as they are released.*





# Columbia Accident Investigation Board

## Recommendation 3.2-1

Initiate an aggressive program to eliminate all external tank thermal protection system debris shedding at the source with particular emphasis on the region where the bipod struts attach to the External Tank. [RTF]

### BACKGROUND

Although this recommendation addresses threats from loose hardware generated during the launch of the Space Shuttle, the International Space Station (ISS) Program recognizes that the safety of the ISS vehicle and other visiting vehicles also depends on avoidance of threats from uncontrolled debris shed from ISS elements or visiting vehicles.

### ISS PROGRAM IMPLEMENTATION

The ISS is designed to avoid debris generation by the orbital vehicle and visiting vehicles (i.e., Shuttle, Soyuz, Progress, Automated Transfer Vehicle, H-II Transfer Vehicle). Existing NASA requirements such as SSP 30426, *Contamination Control Requirements*, impose limits upon generation of external contaminants. SSP 50235, *Interface Definition Document for International Space Station Visiting Vehicles*, includes applicable requirements for visiting vehicles.

Operational steps are taken to preclude threats associated with potential debris sources. Technicians and quality personnel conduct inspections to eliminate any foreign object debris prior to launch. Closeout imagery of the cargo records the general level of compliance and aids troubleshooting. During orbital operations, NASA flight rules, procedures, and training do not permit the jettison of solid materials into space in proximity of ISS. If deemed necessary, objects to be jettisoned are jointly coordinated and sent on a safe trajectory that precludes return to the ISS. Overboard dumping of wastes in space is minimized and tightly controlled by NASA and the International Partners. Elimination of Shuttle waste water dumps while docked to ISS is currently under review.

The ISS also has operational controls that reduce the risks of impacts between ISS elements. For example, robotic and extravehicular activity crew maneuvers are analyzed, trained, and performed with extreme care to prevent hazardous contacts. Visiting vehicle activities are choreographed to minimize docking port relocations and improper contact.

Periodic recorded imagery from visiting vehicles and external cameras helps to verify the current safe condition of the ISS exterior. Ground-based radar tracking reported to NASA by the U.S. Air Force provides additional useful information on orbital debris threats.

### STATUS

Existing risk mitigation measures are in place to control and assess this potential hazard. ISS Program management, design engineers, crewmembers, flight controllers, training instructors, and safety teams continue to ensure risk mitigation.

Lessons learned from near misses during early assembly activities have driven increased use of tools to model the current position of external hardware and increased focus on the importance of operational controls.

### FORWARD WORK

The ISS Program will exercise continued diligence in the use of design and operational controls.

### SCHEDULE

Ongoing.



# **Columbia Accident Investigation Board**

## ***Recommendation 3.3-2***

Initiate a program designed to increase the Orbiter's ability to sustain minor debris damage by measures such as improved impact-resistant Reinforced Carbon-Carbon and acreage tiles. This program should determine the actual impact resistance of current materials and the effect of likely debris strikes. [RTF]

The underlying intent of this recommendation is addressed by Part 1, R4.2-4, and Part 2.1, ISS Continuous Improvement Action ISS-8.



# **Columbia Accident Investigation Board**

## ***Recommendation 3.3-1***

Develop and implement a comprehensive inspection plan to determine the structural integrity of all Reinforced Carbon-Carbon system components. This inspection plan should take advantage of advanced non-destructive inspection technology. [RTF]

The underlying intent of this recommendation is addressed in Part 1, R4.2-4.





# Columbia Accident Investigation Board

## Recommendation 6.4-1

For missions to the International Space Station, develop a practicable capability to inspect and effect emergency repairs to the widest possible range of damage to the Thermal Protection System, including both tile and Reinforced Carbon-Carbon, taking advantage of the additional capabilities available when near to or docked at the International Space Station.

For non-Station missions, develop a comprehensive autonomous (independent of Station) inspection and repair capability to cover the widest possible range of damage scenarios.

Accomplish an on-orbit Thermal Protection System inspection, using appropriate assets and capabilities, early in all missions.

The ultimate objective should be a fully autonomous capability for all missions to address the possibility that an International Space Station mission fails to achieve the correct orbit, fails to dock successfully, or is damaged during or after undocking. [RTF]

### BACKGROUND

The International Space Station (ISS) Program is working with the Space Shuttle Program to develop a method to inspect and affect emergency repairs to the Space Shuttle Thermal Protection System. These efforts are documented in Volume 1 of *NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond*, reference Sections 6.4-1 and SSP-3.

The ISS Program has extensive existing visual inspection capabilities and instrumentation to determine the health of its vehicle. This instrumentation permits many issues to be diagnosed without visual imagery. To meet the intent of this recommendation, the ISS visual inspection requirements and implementation details were examined to assess their adequacy.

Additionally, ISS has on-board maintenance and repair capabilities that help to ensure vehicle and crew safety. This includes on-board spares, tools, materials, and repair procedures.

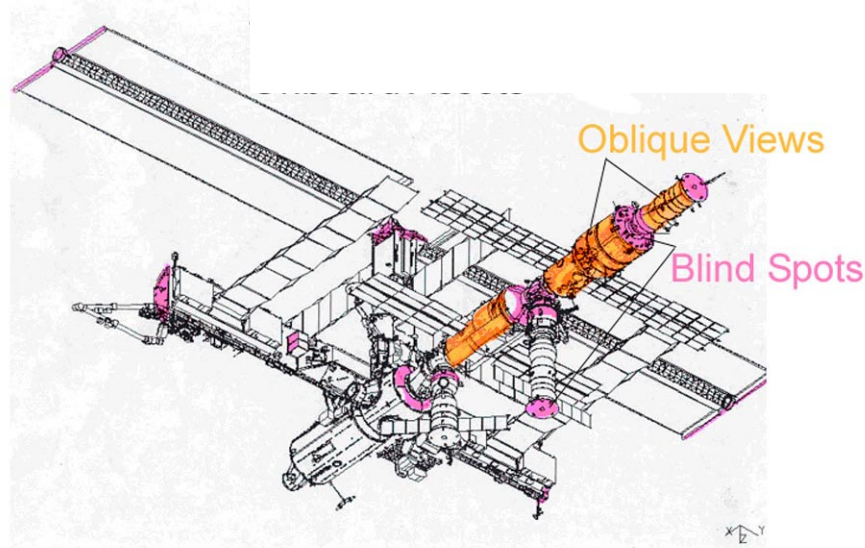
### ISS PROGRAM IMPLEMENTATION

Inspection requirements for internal ISS systems and external ISS systems were reviewed. Internal systems inspection requirements were found to be adequately documented, and these requirements were satisfactorily implemented. External ISS systems inspection requirements relied heavily on photos taken by a visiting/departing Space Shuttle. Implementation of the external viewing requirements without the Shuttle was found to

be inadequate. In response to this situation, the ISS Program has developed a systematic approach for performing an exterior imagery survey by on-board assets.

Under the leadership of the ISS Mission Evaluation Room, an imagery team was established to identify specific external survey imagery requirements; collect, store, and disseminate the imagery; review collected imagery; report their findings; and lead a follow-up investigation of potential anomalies when indicated. The imagery team developed a plan to obtain the necessary images from truss-mounted cameras, robotic system cameras, and crew views through ISS module windows. For imagery taken by the crew, the team identified video quality requirements that can be satisfied with cameras on board the ISS.

The ISS Program has instituted a plan to periodically perform these external surveys. The external surveys support hardware configuration verification, assessment of material degradation, and identification of visible anomalies; provide a historical set of images to assess the long-term progression of degradation; and facilitate future problem resolution. On-board assets provide viewing capability for a significant portion of the vehicle's exterior. However, some surfaces cannot be viewed with on-board assets alone, as shown in Figure 6.4-1.1. Viewing these surfaces requires imagery supplied by other remote assets, such as extravehicular activity (EVA) or visiting vehicles. Note that Figure 6.4-1.1 assumptions include a fully functional ISS robotic and camera systems.



**Figure 6.4-1.1. ISS external surface views that are limited when using on-board assets.**

Dedicated external surveys are augmented by imagery collected during EVAs. During NASA EVAs, helmet camera video and still imagery are typically used as assembly closeout documentation and to augment crewmember descriptions of the conditions or the anomalies they observe. During Russian EVAs, a hand portable video camera known as Glisser is used when necessary.

In terms of improving vehicle maintenance and repair capabilities, NASA has specific new tools that have been in development for several years. These tools include an external fluid line repair kit and a manual electrical cable tester for internal wiring inspections. To extend Shuttle docked duration for science, cargo transfers, and repair activities, the ISS and Shuttle Programs are coordinating the development of a power transfer system. As described by ISS Continuous Improvement Action ISS-8, an infrared camera system is also being developed that can be used for identification of leaks and thermal performance degradations.

## STATUS

The portion of the first periodic ISS external survey that uses external ISS cameras is complete. The imagery is available in the ISS Digital Imagery Management System. In addition, initial external imaging has been conducted on a portion of the Service Module and

Functional Cargo Block using the Space Station Remote Manipulator System.

A team composed of experts, representing each subsystem, the external environment, and the Kennedy Space Center has reviewed the imagery. The results indicate that the ISS exterior hardware is generally performing within specifications. In addition, several thermal blankets were scrutinized for proper configuration, and previously undetected discoloration was observed on a heat rejection system radiator. As expected, external contamination or degradation was noted on several surfaces. No significant anomalies have yet been revealed by the initial survey.

## FORWARD WORK

The remainder of the exterior survey, using robotic assets and crew observation, is yet to be performed. Specific areas of vulnerability will be identified for inspection. It is then anticipated that these inspections, along with the subsequent analysis and reports, will be completed by April 2004. The periodic ISS exterior surveys will continue semiannually for areas viewable with the external cameras and annually for those areas only visible with robotic or crew observation capabilities. The frequency at which the surveys (or portions of the surveys) are performed will be adjusted based on survey findings.

New ISS modules will provide further vantage points through windows for external surveys of ISS surfaces and systems. Furthermore, two additional external video cameras will be installed on truss segments increasing the external mapping capability. The future robotic arm enhancement called the Special Purpose Dexterous Manipulator will have built-in video cameras that can be used for detailed inspections.

NASA is currently certifying EVA digital still cameras to be deployed by return to flight (RTF). Once successfully certified, these cameras could be used to obtain high-resolution imagery that can be downlinked after an EVA for analysis and can be used to inspect areas that cannot be viewed by external video cameras or through ISS windows.

As in the past, upon return to flight, Shuttle imagery assets will be used to survey ISS external surfaces. Orbiter-based imagery provides views of ISS external surfaces not visible from ISS assets and supplies additional views of areas from different perspectives.

The Soyuz vehicles docked to the ISS are inspected to the extent possible. Due to the rendezvous and docking attitude of the Soyuz with respect to the ISS, it is not current practice to inspect or obtain imagery of the entire Soyuz vehicle on orbit. The ISS Program, in coordination with our International Partners, will evaluate the need for additional requirements in support of external inspection of the Soyuz vehicle.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Operations	Apr 04	Complete first periodic exterior survey
ISS Operations	Semiannually	Continuing periodic exterior survey using external cameras
ISS Operations	Annually	Continuing periodic exterior survey using robotic and crew survey
ISS Operations	Ongoing	Anomaly resolution and spot imagery support



## ***Columbia Accident Investigation Board***

### ***Recommendation 3.3-3***

To the extent possible, increase the Orbiter's ability to successfully re-enter the Earth's atmosphere with minor leading edge structural sub-system damage.

The underlying intent of this recommendation is addressed in Part 1, R4.2-4.



# ***Columbia Accident Investigation Board***

## ***Recommendation 3.3-4***

In order to understand the true material characteristics of Reinforced Carbon-Carbon components, develop a comprehensive database of flown Reinforced Carbon-Carbon material characteristics by destructive testing and evaluation.

The underlying intent of this recommendation is addressed in Part 1, R4.2-4.



# ***Columbia Accident Investigation Board***

## ***Recommendation 3.3-5***

Improve the maintenance of launch pad structures to minimize the leaching of zinc primer onto Reinforced Carbon-Carbon components.

This recommendation is not applicable to the ISS.



# Columbia Accident Investigation Board

## Recommendation 3.8-1

Obtain sufficient spare Reinforced Carbon-Carbon panel assemblies and associated support components to ensure that decisions related to Reinforced Carbon-Carbon maintenance are made on the basis of component specifications, free of external pressures relating to schedules, costs or other considerations.

### BACKGROUND

The International Space Station (ISS) has no Reinforced Carbon-Carbon panels; however, there are a number of systems that are required to provide life support and sustain operations. Focusing on the importance of spares to minimize decisions that would be subject to schedule pressure, the ISS Program reviewed its spares provision plans and processes for adequacy. The ISS Program plans and processes were determined to be adequate.

After the Shuttle accident and in response to the *Columbia* Accident Investigation Board recommendations, the ISS Program reviewed its logistics and maintenance plans to ensure that sparing plans are adjusted for the extended Space Shuttle downtime. This process continues as the downtime is extended and critical decisions affecting spares must be made. A spare is currently pre-positioned on orbit for many of these critical orbital replacement units (ORUs). Since the loss of *Columbia*, Progress and Soyuz capacity has limited the ability to deliver limited-life items and large ORUs to orbit and the Progress vehicle cannot return hardware to the ground for repair, although a limited number of small items are being returned on the Soyuz.

### ISS PROGRAM IMPLEMENTATION

The ISS Program uses a combination of simulation analysis and in-depth technical understanding to determine sparing for the ISS. Functional availability is the chief criteria used to determine adequacy of sparing. This methodology uses a predictive measure to assess the continuous on-orbit operation of ISS. Availability is defined as the percentage of time that an ORU or a function is operating. Key data and assumptions for functional availability include reliability data, spares quantities and locations, repair times, redundancy, manifest limitations (flights per year, cargo capability), crew limitations, and on-orbit stowage locations. Reliability data include items such as mean time

between failures (MTBF), duty cycle, induced failure factor, and condemnation rates.

ORU data were obtained from the ISS Prime contractor Boeing and its vendors to understand the hardware and failure impacts. Special attention was placed on hardware performing a critical function to ensure that the proper number of spares is procured.

The ISS Program analyzed the potential for critical failures at each stage of assembly, and plans are in place to cover future ISS configurations.

### STATUS

Due to the Shuttle fleet being grounded, the ISS Program reassessed its on-orbit and resupply approach. Currently, the Russian Progress and Soyuz launch vehicles are the only means of delivering spares to orbit. With a few exceptions due to size constraints, the Progress vehicle volume meets the demands for the ISS to be able to sustain its internal hardware subject to manifest priorities. Some external hardware cannot be launched to orbit on Russian vehicles, but most required critical spares are already on orbit and most required preventive maintenance ORUs can be resupplied on Progress.

With current manifest constraints, the ISS Program is assessing workarounds to ensure that the necessary spares and items are delivered to orbit. While a backlog of items awaiting delivery to ISS exists, there are no immediate threats to continued ISS crew operations. The ISS Program is also implementing actions to reduce the need to launch additional equipment. For example, the crew is using kits to refurbish hardware on orbit, when possible. For some items, specially designed preventative maintenance tasks are being performed to extend hardware lifetime.

### FORWARD WORK

The focus of the current logistics and resupply review is to maintain and sustain the ISS and conduct safe crew

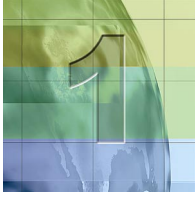


operations during the Shuttle downtime. Although spares provisioning and other logistics discipline reviews are a continual process in this Program, future reassessments of the overall adequacy of spares for the sustainment of the ISS are planned. Of particular concern are spares of crew health-related equipment, such as exercise equipment and atmospheric monitoring. Recent experience with components of the Crew Health Care System highlights the need for thorough analysis and discussion of those areas critical to continuing operations during the Shuttle downtime and adequate up mass and down mass are essential elements of any risk mitigation plan.

The ISS Program will continue activities to lessen dependence on Shuttle resupply. We are continuing to evaluate on-orbit repair of some ORUs rather than replacement to make best use of limited resupply.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
Flight Medicine	TBD	Reassess medical support requirements
ISS Program Logistics	Ongoing	Develop and implement plans to keep ISS hardware operational during Shuttle downtime



# Columbia Accident Investigation Board

## Recommendation 3.8-2

Develop, validate, and maintain physics-based computer models to evaluate Thermal Protection System damage from debris impacts. These tools should provide realistic and timely estimates of any impact damage from possible debris from any source that may ultimately impact the Orbiter. Establish impact damage thresholds that trigger responsive corrective action, such as on-orbit inspection and repair, when indicated.

### BACKGROUND

Although the *Columbia* Accident Investigation Board's (CAIB's) action was specific to the debris impacts on a Shuttle, NASA has also initiated steps to assess all International Space Station (ISS) analytical models and tools that are used to support on-orbit operations, anomaly resolution, and decision-making processes. ISS Program boards are reviewing the verification, conservatism, and uncertainty associated with analytical models to ensure that the model fidelity and assumptions, limitations, and boundary conditions are understood and are acceptable. The boards will address any identified improvements required as a result of their assessment.

### ISS IMPLEMENTATION

The ISS Program is in the process of assessing all of its analytical models. The models included in the assessments are those used for assembly and sustaining operations on the vehicle, and for flight rule or procedure development, and those developed to support on-orbit anomalies. The assessments will determine the adequacy of the current level of validation, verification, and configuration control of analytical models to ensure a consistent level of control across all subsystem teams.

Recognizing that the interpretation of data produced by math models is as important as the accuracy of the models themselves, the ISS Program has implemented steps to ensure adequate communication of the uncertainty in math modeling results. As pointed out in the CAIB Report, "engineering solutions presented to management should have included a quantifiable range of uncertainty and risk analysis". An effort to understand sources of uncertainty in math modeling was initiated to establish a common knowledge base and terminology to be used across the Program. The ISS Program has hosted a short course on "Experimentation and Uncertainty Analysis" for analysts and managers representing Program subsystem teams.

To ensure consistent and thorough communication of conservatism and uncertainty, a presentation template has been developed as an aid for presenting analytical data to ISS Program boards or Anomaly Resolution Teams. The presentation format includes specific information on inputs to the analyses, model verification history, uncertainty factors, and conservatism. The intent of the template is to facilitate the communication between analysts and decision makers so that the key assumptions underlying the analyses, results, and solution options are understood in terms of associated risk and potential consequences.

### STATUS

To accomplish the intent of this recommendation, three parallel but related efforts are being pursued.

1. A generic data presentation template has been developed and is being implemented by the ISS Mission Evaluation Room (MER) for its technical reports to the ISS Mission Management Team (IMMT). A similar template is being developed for presentations to ISS boards that contain critical-model-produced data necessary for decisions. The subsystem teams use this template to develop specific formats for communicating the uncertainty and conservatism included in the analyses for their specific disciplines.
2. The ISS Program is investigating the adequacy of existing analytical models and is committed to a continuous process of review to ensure adequate precision and accuracy of results.
3. An effort to quantify uncertainty in math-model-produced analysis has been begun. This was kicked off with a short course on "Experimentation and Uncertainty Analysis" taught to a group of analysts and managers from each subsystem. Several of the subsystem teams have begun to investigate methods for approximating the uncertainty of model analysis.

## FORWARD WORK

As model assessments are completed, recommendations of areas where additional resources, testing, and/or on-orbit instrumentation can be used to reduce analysis uncertainty and Program risk will be identified and brought to the Space Station Program Control Board for approval. Guidelines for configuration control of models will be drafted and implemented to be applicable to all subsystem teams.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
IMMT, MER	Nov 03 (Complete)	Attend training on uncertainty analysis
ISS Operations	Nov 03 (Complete)	Develop MER/IMMT presentation templates
ISS Operations	TBD	Develop ISS board presentation templates
ISS Program Integration	Feb 04	Guidelines for Configuration Control of analytical models
ISS Program Integration	Mar 04	Subsystem model assessments and develop recommendations



# ***Columbia Accident Investigation Board***

## ***Recommendation 3.4-1***

Upgrade the imaging system to be capable of providing a minimum of three useful views of the Space Shuttle from liftoff to at least Solid Rocket Booster separation, along any expected ascent azimuth. The operational status of these assets should be included in the Launch Commit Criteria for future launches. Consider using ships or aircraft to provide additional views of the Shuttle during ascent. [RTF]

The underlying intent of this recommendation is addressed in Part 1, R6.3-2, R6.4-1, and R10.3-1.



# ***Columbia Accident Investigation Board***

## ***Recommendation 3.4-2***

Provide a capability to obtain and downlink high-resolution images of the External Tank after it separates. [RTF]

The underlying intent of this recommendation is addressed in Part 1, R6.3-2, R6.4-1, and R10.3-1.

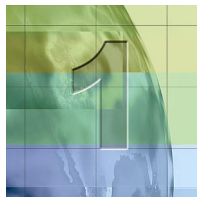


# ***Columbia Accident Investigation Board***

## ***Recommendation 3.4-3***

Provide a capability to obtain and downlink high-resolution images of the underside of the Orbiter wing leading edge and forward section of both wings' Thermal Protection System. [RTF]

The underlying intent of this recommendation is addressed in Part 1, R6.3-2, R6.4-1, and R10.3-1



# Columbia Accident Investigation Board

## Recommendation 6.3-2

Modify the Memorandum of Agreement with the National Imagery and Mapping Agency (NIMA) to make the imaging of each shuttle flight while on orbit a standard requirement. [RTF]

### BACKGROUND

The International Space Station (ISS) Program will take advantage of national assets to support on-orbit assessment of the ISS external condition.

### ISS IMPLEMENTATION

NASA has already concluded a Memorandum of Agreement with the National Geospatial Intelligence Agency (formerly known as the National Imagery and Mapping Agency) that provides for on-orbit assessment and includes ISS support. In addition, NASA has initiated discussions across the interagency community to explore the use of appropriate national assets to evaluate the condition of the Orbiter vehicle and the ISS.

Since this action may involve receipt and handling of classified information, the appropriate security safeguards will be observed during its implementation.

### STATUS

The ISS Program has determined which positions/personnel will require access to data obtained from external sources. The ISS Program will ensure that appropriate personnel are familiar with the general capabilities available for on-orbit assessment and that

appropriate personnel are familiar with the means to gain access to that information.

The ISS Program has already begun the process to obtain the required clearances.

### FORWARD WORK

The operational teams will develop standard operating procedures to implement any agreements with the appropriate government agencies.

An internal NASA process is being used to track clearances and training of personnel.

### SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Mission Operations	TBD	Initial plan for personnel training
ISS Mission Operations	TBD	Initial ISS operational procedures





# Columbia Accident Investigation Board

## Recommendation 3.6-1

The Modular Auxiliary Data System instrumentation and sensor suite on each Orbiter should be maintained and updated to include current sensor and data acquisition technologies.

## Recommendation 3.6-2

The Modular Auxiliary Data System should be redesigned to include engineering performance and vehicle health information and have the ability to be reconfigured during flight in order to allow certain data to be recorded, telemetered, or both, as needs changes.

## BACKGROUND

The Modular Auxiliary Data System (MADS), which is also referred to in the *Columbia* Accident Investigation Board Report as the “OEX recorder,” is an Orbiter recorder for collecting engineering performance data. MADS records data on the environment experienced by and the responses of the Orbiter during ascent and entry.

Although the International Space Station (ISS) does not use a MADS recorder, the ISS still depends on telemetry for engineering performance data. Because the ISS does not return to the ground for processing, most performance data are downlinked from orbit.

## ISS PROGRAM IMPLEMENTATION

Engineering performance data are required throughout the life of the ISS. The S-Band telemetry from ISS shares bandwidth with two channels of compressed audio. Data exchange with the ground is via the tracking and data relay satellite system in geosynchronous orbit. All of the available telemetry bandwidth of the S-Band has been fully subscribed since the U.S. Laboratory module was deployed in 2001.

ISS Program requirements control what data are downlinked. These requirements include vehicle performance assessment as well as real-time operational assessment. All telemetry users have the opportunity to submit requirements to this process. When requirements exceed downlink bandwidth capability, multiple telemetry formats are established to facilitate sharing.

As individual required sensors fail or become unreliable, the ISS Program replaces the sensor, recalibrates the sensor, or identifies an alternate approach to gathering the information. As new instrumentation needs are identified, add-on capabilities are procured.

Pre-planned Product Improvements (P<sup>3</sup>I) to the ISS avionics will address upgrades to engineering performance data capabilities and are focused at increasing the bandwidth for telemetry.

## STATUS

The ISS Program has not identified any risks to sustained operation of the ISS due to deficient instrumentation.

Systems that perform functions much like the sensor suite and recorders of the MADS were defined as formal ISS requirements, implemented as part of the basic Program, and are to be maintained for the life of the Program. The equivalent to the MADS system is the Structural Dynamic Measurement System. That system is comprised of 33 accelerometers, 38 strain gauge bridges, two signal conditioners, connecting wires, and software. The accelerometers are mounted on all truss segments without solar arrays. The strain gauges are mounted on the critical rotating equipment. The signal conditioning units boost measurement inputs and record and buffer the data so the data can be sent to the ground.

The ISS Program identified additional requirements for structural measurements and environmental characterization after the initial design of the ISS. In each case, innovative solutions were accommodated without the addition of new cabling. The first of these new requirements measures structural strains and accelerations in the pressurized volume to characterize dynamic response. Internal wireless instrumentation was developed to implement this capability. The second of the new requirements measures the voltage potential of the ISS compared to the ambient plasma as well as the ionospheric plasma electron density and electron temperature. The Floating Potential Measurement Unit measures the existence and severity of spacecraft charging

hazards. Real data on spacecraft charging characteristics permit hazard control strategies that minimize overall risk to the vehicle and crew.

To increase bandwidth for sending telemetry to the ground, two approved enhancements are in work. One will upgrade the ISS computers to increase their data processing and storage capability and to make all the data available for Ku-band downlink. This upgrade will allow all ISS telemetry to be downlinked continuously. The second enhancement will increase the bandwidth of the Ku-band data stream to the ground from 50 megabits per second to 150 megabits per second. The change also increases data transmission from the ground station at White Sands, New Mexico, to Houston and Huntsville. The conceptual design and testing of this upgrade is under way.

## FORWARD WORK

The ISS Program will continue implementation of upgrades to the laptop computers and Ku-band systems to provide increased downlink bandwidth.

Future avionics systems upgrades will be assessed through the P<sup>3</sup>I process.

## SCHEDULE

For the computer upgrade:

Responsibility	Due Date	Activity/Deliverable
ISS Program	Jun 04	Preliminary Design Review
ISS Program	Dec 04	Detailed Design Review
ISS Program	Dec 05	Delivery of first flight unit

For the Ku-Band upgrade:

Responsibility	Due Date	Activity/Deliverable
Mission Systems Development Group	Dec 03 (Complete)	Replace satellite link between White Sands and NASA centers with fiber-optic cable
Mission Systems Development Group	Dec 05	Full 150 megabits per second



# Columbia Accident Investigation Board

## Recommendation 4.2-2

As part of the Shuttle Service Life Extension Program and potential 40-year service life, develop a state-of-the-art means to inspect all Orbiter wiring, including that which is inaccessible.

### BACKGROUND

While the Shuttle Program is able to take advantage of performing wiring inspections on the ground, the nature of the International Space Station (ISS) system dictates that physical wiring inspections be performed on orbit. Internal wiring is susceptible to damage when it, or hardware nearby, is manipulated through normal daily activity on the ISS. Plans are in place to perform routine wiring inspections of opportunity in high traffic areas as part of normal ISS systems maintenance. External wiring was designed to operate in the low Earth orbit environment, which includes hazards from micrometeoroids, orbital debris, atomic oxygen, ultraviolet radiation exposure, etc. In addition, the ISS is designed to have redundancy in critical systems. Controls are also in place to minimize manual cable handling prior to launch at Kennedy Space Center. Preflight testing during multi-element integrated tests verifies proper system-level electrical functionality.

### ISS PROGRAM IMPLEMENTATION

Various means are used to control the risk of on-board wire damage. ISS crewmembers are trained to report hardware conditions that are out of the ordinary. When the crew is working in an area that has exposed wires, they report to the ground any time they see fraying or chafing of wires. Crew inspections have resulted in the ground being notified of wiring issues before the wiring problems induced problems with associated hardware. For example, at one point the Service Module food warmer displayed signs of degradation of the protective covering of some wiring. Because the crew was trained to look for this type of anomalous situation, they reported the wiring degradation to the ground and corrective action was taken before any systems anomaly occurred.

Additionally, one function of the ISS Mission Evaluation Review team in the Mission Control Center is to review all telemetry data from the ISS for anomalous signatures. All anomalous signatures are investigated and, where wiring is a possible cause, inspections by the crew are given consideration by the anomaly resolution team.

Even though the ISS elements on orbit have only been in place for up to five years, the ISS Program will evaluate whether additional routine wiring inspections should be implemented in response to aging effects.

### STATUS

The ISS Program has determined that its two-pronged inspection technique is sufficient for this phase of the ISS Program. These techniques can be summarized as:

1. Performing inspections of opportunity when wiring is exposed through normal daily activity or scheduled maintenance.
2. Relying on anomalous hardware signatures from the ISS detected on the ground from telemetry.

Wiring inspections are pursued whenever a branch of a fault tree suggests cabling is a possible cause of an anomalous signature.

### FORWARD WORK

The ISS Program will evaluate whether or not the ISS crews need to be trained to evaluate wiring against specific criteria and/or include wiring criteria within maintenance procedures. NASA will evaluate whether routine wiring inspections should be implemented and if state-of-the-art technology is needed to aid inspections.

The ISS Program will also assess the risks of wiring aging through the whole vehicle life.

The ISS Program will complete the design, certification, and delivery of its manual electrical cable tester (MECT).

### SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Under Review	Assess wiring aging risks and recommend needed actions
ISS Program	TBS	Complete design, certification, and delivery of MECT



## ***Columbia Accident Investigation Board***

### ***Recommendation 4.2-1***

Test and quality the flight hardware bolt catchers. [RTF]

The underlying intent of this recommendation is addressed in Part 2.1, ISS Continuous Improvement Action ISS-12.



# Columbia Accident Investigation Board

## Recommendation 4.2-3

Require that at least two employees attend all final closeouts and intertank area hand-spraying procedures. [RTF]

### BACKGROUND

External Tank final closeouts and intertank area hand-spraying processes typically require more than one person in attendance to execute procedures. Although those closeout processes currently able to be performed by a single person did not necessarily specify an independent witness or verification, that is not the case for International Space Station (ISS) closeouts. For ISS, standard processing practices at Kennedy Space Center (KSC) require independent witness verification.

### ISS PROGRAM IMPLEMENTATION

ISS procedures at KSC were reviewed to confirm that requirements are adequately defined and implemented. In concert with ISS Program requirements, the ISS closeout procedures are documented in Boeing Standard Practice SP-QUAL-002, *ISS Configured for Test and Flight*. The rigorous two-step process to flight closeouts is described in this Boeing document and applies to ISS Prime contractor operations. NASA/ISS Program personnel and the Checkout Assembly and Payload Processing contractor currently close out areas with Work Authorization Documents (WADs) that require both NASA and Boeing quality assurance stamps. These guidelines are being formulated into a Standard Practice and Procedure that will apply to all ISS Program hardware processed at KSC.

The ISS Program has strict guidelines for what will be documented in the WAD, including assurance that closeout photos are taken and that both government and contractor quality assurance personnel accept the area. If changes to closeouts are required, a new WAD is created referencing the previous closeout WAD. At a minimum,

Boeing Engineering, Boeing and government Quality Assurance are mandatory witnesses; and these personnel will determine if Materials and Processing Engineering, Flight Crew representatives, and Thermal Engineering are also required. Any rework will automatically require closeout photography. ISS closeout imagery is further discussed in response to R3.4-1, R10.3-1, and R6.4-1.

### STATUS

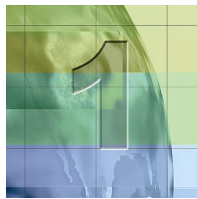
Existing ISS procedures for processing Boeing hardware have been reviewed and determined to meet the *Columbia* Accident Investigation Board recommendation for quality control of critical procedures. These guidelines are being formulated into a Standard Practice and Procedure that will apply to all ISS Program hardware processed at KSC.

### FORWARD WORK

Complete documentation to extend the guidelines to all ISS Program hardware processed at KSC.

### SCHEDULE

Responsibility	Due Date	Activity/Deliverable
KSC	Jan 04 (Completed)	Complete KSC Standard Practice and Procedure



# Columbia Accident Investigation Board

## Recommendation 4.2-4

Require the Space Shuttle to be operated with the same degree of safety for micrometeoroid and orbital debris as the degree of safety calculated for the International Space Station (ISS). Change the micrometeoroid and orbital debris safety criteria from guidelines to requirements.

### BACKGROUND

Micrometeoroid and orbital debris (MMOD) is recognized as a continuing concern for the International Space Station (ISS), the Shuttle, and other spacecraft. The current differences between the ISS and Shuttle risk for critical damage from MMOD are based on the original design specification for each vehicle. The ISS was designed for long-term exposure to both micrometeoroids and orbital debris, whereas the original Shuttle design specification was to provide short-term protection from micrometeoroids only because there was not any recognized threat from orbital debris until the late 1980s (i.e., well after Shuttle design was completed). To meet ISS requirements, robust shielding protection and operational procedures are in place on ISS, or will be implemented during upcoming assembly missions, to reduce the risk of MMOD-induced threats to the crew and vehicle. In addition, ISS hardware is designed to allow MMOD shielding to be augmented over the life of the Program.

### ISS PROGRAM IMPLEMENTATION

NASA has implemented a three-pronged approach to reducing risks to the vehicle and crew from MMOD on ISS:

1. Implementing robust meteoroid/orbital debris shielding on the habitable modules where the crew lives and works, as well as on all external propellant tanks, pressurized vessels, and control moment gyroscopes.
2. Performing collision avoidance maneuvers during ISS operations to prevent impact from all orbital debris that can be tracked from the ground.
3. Developing contingency procedures and risk mitigation techniques in the event an MMOD impact causes a leak in the pressure shell of the habitable modules. For instance, atmospheric pressure sensors are on board to enable initial detection of a significant leak above normal losses and handheld ultrasonic tools have been delivered on orbit to aid in locating a leak

internally. While locating small leaks masked by surrounding structures, audibly active mechanisms and normal atmospheric flows can be difficult; when an actual leak site is found, patch kits are available to seal a reasonably sized leak from inside the ISS modules. Crew training and ground operational procedures are in place to react properly to a depressurization event (e.g., verify valves are properly closed, listen with sensitive audible sensors, isolate portions of the cabin, conduct internal repairs and evacuate the ISS if warranted).

The MMOD shields on ISS are the most capable shields ever developed and flown on a spacecraft. An example of the shielding used to protect the U.S., Japanese, and European habitable modules is given in Figure 4.2-4.1. These shields measure 4 inches to 6 inches from inside to outside; and they consist of multiple layers of aluminum, ceramic cloth, and ballistic protection fabrics (i.e., “bullet-proof” materials). The Russian-provided *Zarya* Functional Cargo Block (FGB) module is protected by different shielding configurations but with similar protection capability as the U.S. shielding. The approach to *Zvezda* Service Module (SM) shielding is to launch with minimal shielding and outfit the module with “augmented” shielding on orbit by extravehicular activity. SM shield augmentation has begun, with some augmentation shields in place and others to be added soon after Shuttle return to flight. Figure 4.2-4.2 illustrates SM augmentation shields. In addition, NASA and our Russian Partners are developing plans to enhance MMOD protection of Soyuz and Progress vehicles. Hypervelocity impact tests and analysis have been performed that demonstrate significant reductions in MMOD risk for these vehicles (by a factor of five) by adding approximately 25 kg of additional shielding on the ground.

An international group led by the ISS Program is coordinating plans for development of improvements to the leak detection and repair capabilities. This includes both internal and externally applied solutions.

STATUS

MMOD shielding design and implementation is completed for FGB, Node 1, Pressurized Mating Adapters, U.S. Laboratory Module, Airlock, control moment gyros, and external pressurized tanks.

Final shield testing, evaluation, and verification is ongoing for hardware to be delivered to ISS in future, including Node 2, cupola, Node 3, Centrifuge Accommodation Module, and European and Japanese modules.

Augmentation of SM shielding is under way. Efforts are also under way to expedite implementation of enhanced MMOD protection for Progress and Soyuz vehicles.

NASA is evaluating short-term operational methods to reduce risks of MMOD impacts, including closing hatches to the Progress and the Russian docking compartment when possible.

As part of the effort to identify and trend actual MMOD impact effects on ISS, NASA has implemented regular inspections of all ISS windows. ISS is also using Shuttle-returned modules to study representative MMOD effects and mitigation performance. NASA is also implementing regular inspections of other external

surfaces, such as the large radiators that are attached to the ISS truss.

FORWARD WORK

NASA is working with our Russian partners to expeditiously implement augmented shielding for SM and enhanced protection for Progress and Soyuz. Current planning for expedited MMOD shielding calls for SM augmentation shielding to be delivered on ISS flights 13A.1 and UF-4 or UF-4.1. Soyuz MMOD enhancement could be available as early as ISS flight 9S, and Progress protection enhancement may be available as early as ISS flight 13P.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Ongoing	Continue MMOD shielding assessments for U.S. elements
ISS Program	TBD	Coordinate with Russian partners on MMOD shielding

(Typical Configurations Illustrated)

- U.S., Japanese, and European modules employ “Stuffed Whipple” shielding on the areas of their modules exposed to the most impacts from orbital debris & meteoroids (i.e., red areas of graphic – forward and sides)
  - Nextel™ ceramic cloth and Kevlar™ fabric materials used in the intermediate bumper
  - shielding capable of defeating ~1.3cm aluminum sphere at 7 km/s, normal impact

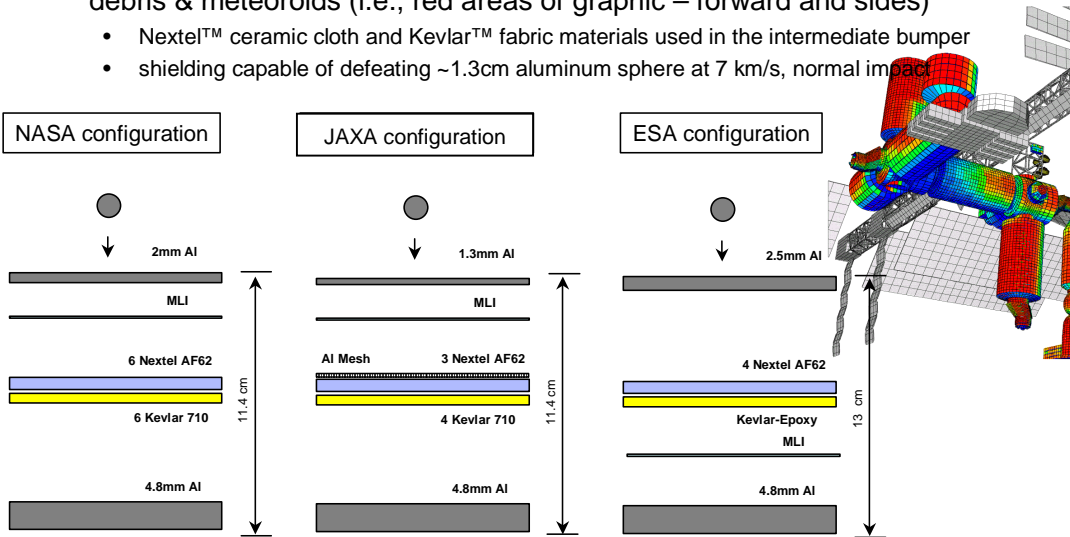


Figure 4.2-4-1. Typical MMOD shielding configurations for U.S., European, and Japanese modules



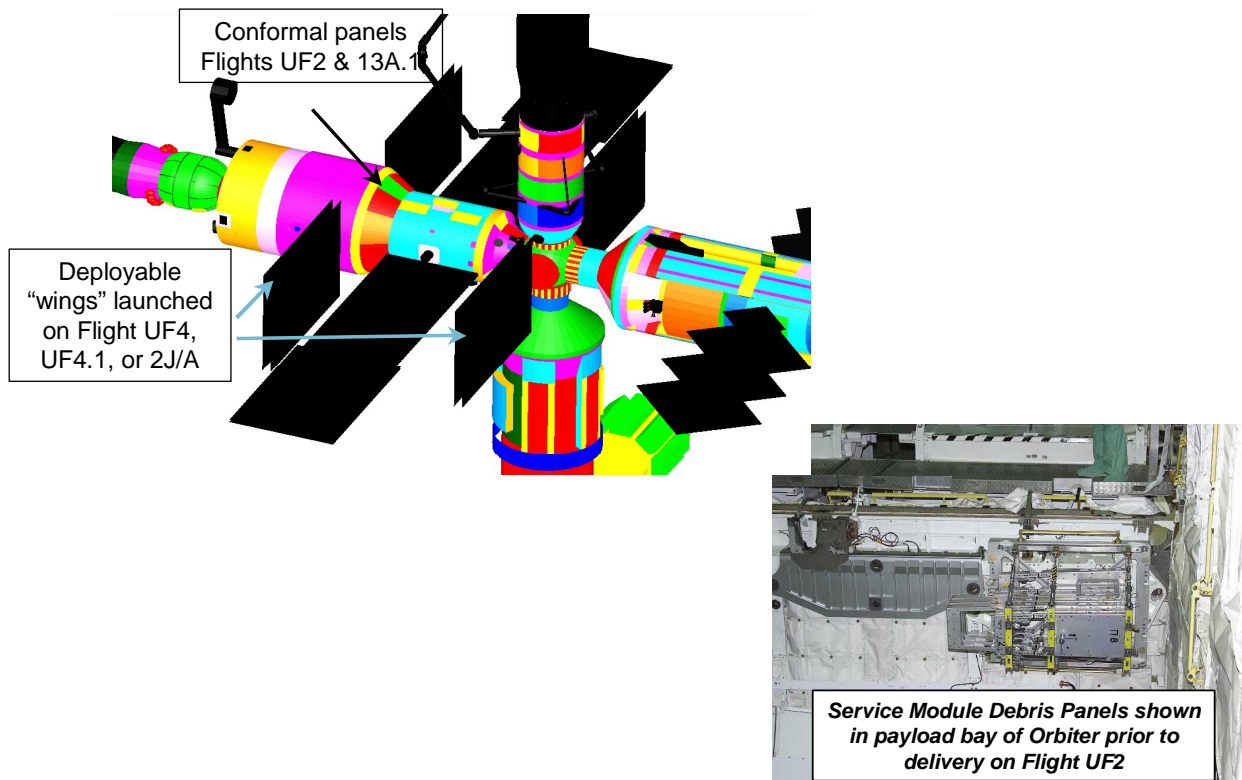


Figure 4.2-4-2. Russian SM augmentation shields



# Columbia Accident Investigation Board

## Recommendation 4.2-5

Kennedy Space Center Quality Assurance and United Space Alliance must return to the straightforward, industry standard definition of “Foreign Object Debris,” and eliminate any alternate or statistically deceptive definitions like “processing debris.”

### BACKGROUND

In 2001, Kennedy Space Center (KSC) Shuttle Processing recategorized foreign object debris (FOD) into two categories, “processing debris” and “FOD.” FOD was defined as debris found during the final or flight-closeout inspection process. All other debris was labeled processing debris. The categorization and subsequent use of two different definitions of debris led to a perception that processing debris was not a concern. The International Space Station (ISS) Program assessed how FOD was treated within ISS facilities.

### ISS PROGRAM IMPLEMENTATION

An independent assessment has been completed that resulted in several recommendations for improvements to KSC’s FOD program.

As the responsible contractor for payload processing at KSC, the Checkout Assembly and Payload Processing Services contractor maintains all elements of a formal FOD program, including identification, prevention, control, and correction. Their responsibilities exclude metrics and trend analysis. For ISS hardware, the contractor is bound to specific ISS Program cleanliness requirements such as *Space Station Requirements for Materials and Processes* (SSP 32233) and *Space Station External Contamination Control Requirements* (SSP 30426). These requirements flow down to local Standard Practices and Procedures (SPP) cleanliness requirements such as *Payload Processing Work Area Rules* (SPP O-01) and *KSC Payload Facility Contamination Control Requirements Plan* (K-STSM-14.2.1). These standards maintain the proper policy and procedures that address FOD and contamination prevention, control, and correction. Specific areas addressed in these standards include work area surveillance and rules, FOD barriers, roles and responsibilities, tool controls, garments and gowning, equipment and material controls, access controls, walkdowns and inspections, ingress and egress monitoring, employee awareness, and training.

Even though a robust contamination control process is already in place, KSC ISS engineers will evaluate its consistency with Shuttle FOD Control Plans under development and evaluate possible additions of metrics and trend analysis.

Since the ISS elements and payload carriers eventually become integrated into the Shuttle payload bay before launch, it is logical to define, measure, and manage FOD produced during payload ground operations with processes, standards, and procedures similar to the Shuttle vehicle. ISS Material and Processes (M&P) engineers will work closely with Shuttle engineers to adopt one definition of FOD.

### STATUS

Currently, the ISS Program M&P engineers are evaluating whether Program-level requirements documents need to be changed to standard FOD definitions with the Shuttle Program, and whether metrics and trend analysis should be required.

KSC ISS engineers and managers are working with their Shuttle counterparts and are reviewing applicable SPP and other standards as they evaluate a potential need for a formal FOD Control Plan. Working closely with Shuttle engineers will ensure a consistent universal approach to minimize the risk of FOD to flight operations and ISS performance.

An element of the ISS currently undergoing processing for launch was recently detected to contain an excess amount of FOD. The element, Node 2, is undergoing final pre-launch checkouts. As a result of the finding of FOD in Node 2, the processing flow has been adjusted to allow engineers the opportunity to remove the FOD prior to Node 2 launch.

### FORWARD WORK

KSC ISS engineers will remain in lockstep with both ISS and Shuttle Programs as they document a formal FOD

Control Plan that will include a universal definition of FOD.

ISS assembly elements, logistical carriers, and science experiments come from many different developers; i.e., NASA, International Partners, ISS contractors, vendors, commercial science entities, and academia. NASA will levy FOD requirements on each of these hardware developers to ensure a consistent and effective approach to FOD control.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
KSC	Ongoing	Continue assessment of FOD program



# Columbia Accident Investigation Board

## Recommendation 6.2-1

Adopt and maintain a Shuttle flight schedule that is consistent with available resources. Although schedule deadlines are an important management tool, those deadlines must be regularly evaluated to ensure that any additional risk incurred to meet the schedule is recognized, understood, and acceptable. [RTF]

### BACKGROUND

Schedules are integral parts of program management and provide for the integration and optimization of resource investments across a wide range of connected systems. The International Space Station (ISS) Program is just such as system, and it needs to have a visible schedule with clear milestones to effectively achieve its mission. The ISS Program will not compromise system safety in our effort to optimize schedules. All activities are associated with very specific milestones that must be completed for mission success. If these milestones can be accomplished safely, the scheduled activities occur on time. If a milestone is not accomplished, the schedules are extended consistent with the need for safety. ISS Program management requires greater insight into Program status than that provided by schedules alone. ISS has implemented a suite of Program control tools and processes to monitor schedule-budget compatibility, elevate Program risks, and ensure that system and mission safety are not compromised in an effort to optimize integration.

The ISS on-orbit configuration for a crew of two is stable and does not drive any particular Shuttle launch date. The ISS Program is maintaining assembly hardware processing activities at Kennedy Space Center to ensure that ISS hardware is ready to support assembly when the Space Shuttle returns to flight.

### NASA IMPLEMENTATION

To support NASA's priorities of safe and effective operations, the ISS Program has adopted a development and operations schedule that is consistent with available resources. The ISS and Shuttle Programs' top-level schedules are integrated and assessed for risk through actions of the Joint (Shuttle-Station) Program Requirements Control Board. Furthermore, through implementation of several ISS Program control processes and tools, technical, cost, and schedule risks and their mitigation plans are assessed regularly.

The ISS Monthly Program Review (IMPR) ties technical, cost, and schedule status together for each performing organization and the Program as a whole, using data collected and assessed through tools and processes developed by an office created expressly to implement new Program control techniques. The IMPR comprises, in addition to in-depth reviews of integrated Shuttle-Station schedules, a detailed technical, cost, and schedule status of the ISS Program using the Web-based One NASA Management Information System (MIS) situational awareness tool. The ISS data in the One NASA MIS enable senior managers in the Space Flight Enterprise to review Program performance indicators and risk assessments on a near-real-time basis (Figure 6.2-1-1). Central to this dataset are the key Program performance indicator metrics, sorted by red-yellow-green urgency/impact coded arrows, and backed by more detailed, manager-level performance metrics. These metrics include a Program-wide Performance Measurement System based on earned-value management concepts and technical, cost, and schedule risk status directly from the ISS Risk Management Application (IRMA).

In addition to the IMPR, the ISS Program management team receives an Early Warning System (EWS) monthly report that includes in-depth assessments of ISS business data (tied to schedule and technical status), Performance Measurement System, the One NASA MIS performance indicators, and a quantitative risk assessment of those IRMA risks that are on the official ISS threats list. Special assessments are performed as needed and documented either as special sections of the EWS or as standalone reports. All EWS reports and other ISS assessment products are accessible via the One NASA MIS.

Overall Shuttle and ISS schedules are reviewed by the Deputy Associate Administrator (DAA) for ISS and Space Shuttle Programs (SSP) and the Space Flight Leadership Council. The staff of the DAA for ISS and SSP also participate in daily tag-ups with Program management.

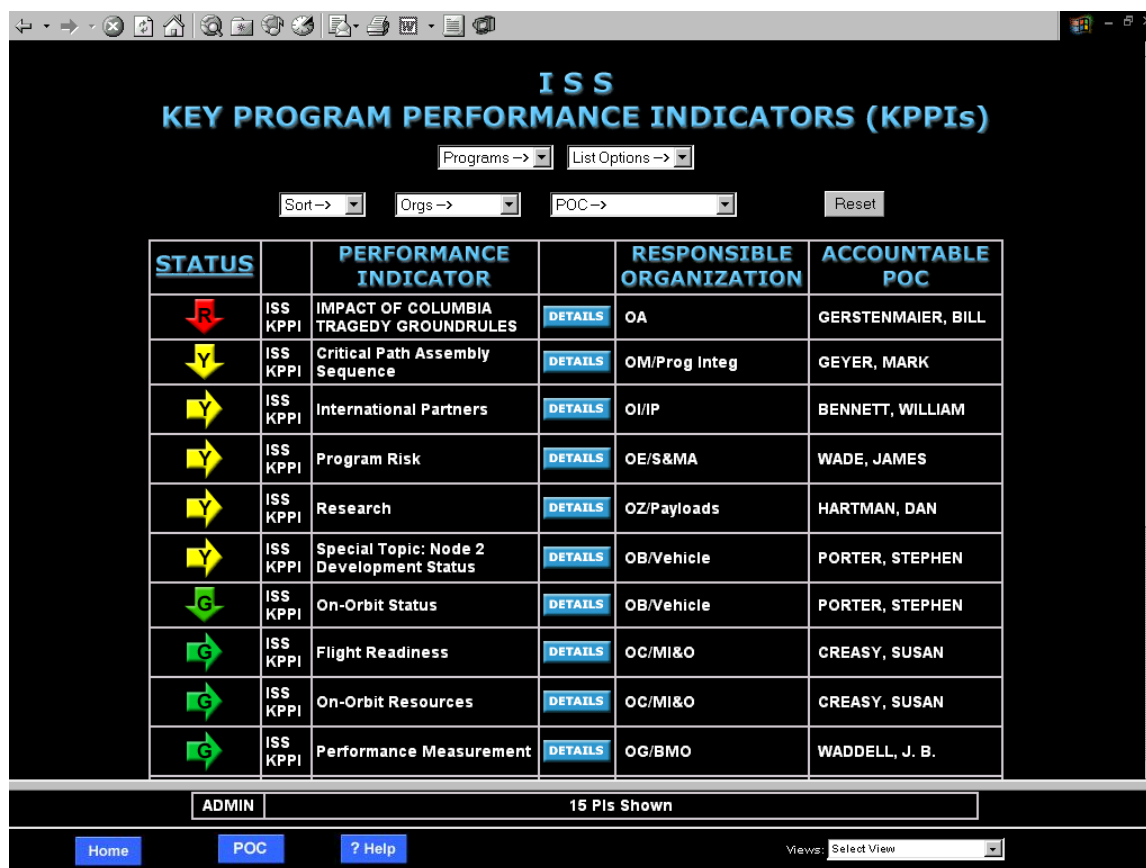


Figure 6.2-1.1 ISS key Program performance indicators

## STATUS

A series of assessments of technical, cost, and schedule issues and risk is in work to provide ISS management with the increased information necessary to support Shuttle return to flight decisions.

## FORWARD WORK

Ongoing efforts to improve ISS Program control tools and processes will continue.

ISS ground rules and constraints documentation is being reviewed to identify and resolve issues that apply to

scheduling and performing mission objectives (e.g., back-to-back extravehicular activities).

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Ongoing	Continue assessment of technical, cost, and schedule issues to support Shuttle return to flight



# Columbia Accident Investigation Board

## Recommendation 6.3-1

Implement an expanded training program in which the Mission Management Team faces potential crew and vehicle safety contingencies beyond launch and ascent. These contingencies should involve potential loss of Shuttle or crew, contain numerous uncertainties and unknowns, and require the Mission Management Team to assemble and interact with support organizations across NASA/Contractor lines and in various locations. [RTF]

### BACKGROUND

Like the Shuttle Mission Management Team (MMT), the International Space Station (ISS) Mission Management Team (IMMT) is responsible for providing programmatic oversight and management direction associated with on-orbit operations of the ISS. The IMMT is responsible for making programmatic and technical decisions on behalf of the ISS Program when decisions must be made outside of the established mission rules and procedures, when on-orbit mission priorities must be adjusted, and when anomalous conditions present a change in risk to the vehicle, crew, and mission success. The ISS Program has initiated a review of the IMMT charter and processes including the adequacy of relevant training plans.

### ISS PROGRAM IMPLEMENTATION

With ISS operations ongoing, the IMMT is continually expected to perform with the rigor and discipline necessary to execute its responsibilities. As documented in its charter, the IMMT meets twice per week to review the status of ongoing ISS operations. During critical ISS operations, the IMMT meets more frequently. The IMMT Executive Secretary maintains a current list of contact information for all IMMT members, and this information is updated regularly.

A proposed update to the IMMT charter has been prepared to take into account lessons learned from operating the ISS for five years, and recommendations from the *Columbia* Accident Investigation Board. The updated charter is in the final stages of review and will then be submitted to the Space Station Control Board (SSCB) for approval. Important modifications to the charter include:

1. Strengthening the process for the review and disposition of on-orbit anomalies and issues.

2. Clearly stating the responsibilities of all IMMT members, including International Partner representatives.
3. Defining procedures for calling a special IMMT, when decisions are needed before the next regularly scheduled IMMT.
4. Clarifying the role of the IMMT in certifying ISS readiness for major mission activities or events.

Training for IMMT members is documented in work instructions that govern the support that key organizations provide in support of the IMMT. Many of these work instructions have been updated in support of this action. The remaining work instructions will be updated to capture training requirements tailored to each individual member.

Training exercises are scheduled for the IMMT in support of critical first-time activities, such as crew exchange on a Soyuz. These simulations include contingency cases that are specifically designed to exercise the decision-making process of the IMMT.

The IMMT is also planning simulations of ISS on-orbit failures that may result in emergency scenarios, including emergency evacuation of the crew. These simulations will include management personnel (i.e., IMMT members) from all Program organizations.

To further ensure that joint MMT/IMMT processes are integrated, the IMMT is participating with the MMT in defining joint simulation cases and will participate fully in all on-orbit training planned for the Space Shuttle MMT.

### STATUS

The updated IMMT charter is in the final stages of review with our International Partners and will be brought to the SSCB for formal baselining.

In addition, some members of the IMMT, including the chairperson and alternate chairperson, have received cultural awareness training. One of the objectives of this training is to sensitize decision makers and meeting leaders to their responsibilities to ensure that all viewpoints are heard and properly addressed.

The ISS Program is joining with the Space Shuttle Program in planning human factors and decision-making training for its members. For example, IMMT members will be given a class on Crew Resource Management in January/February 2004. In early December 2003, the ISS and Shuttle Programs conducted a joint integrated simulation of a docked mission contingency scenario that exercised the latest processes and personnel of the IMMT and MMT.

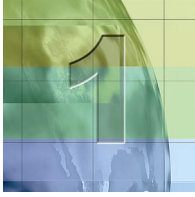
## FORWARD WORK

Ensure that all training requirements are properly documented, and these requirements are properly implemented. Ensure that all IMMT members are given appropriate training.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Nov 03 (Complete)	Draft IMMT Charter update
ISS Program	Dec 03 (Complete)	Conduct joint simulation with Shuttle Program
ISS Program	Apr 04	SSCB approves IMMT Charter revisions





# Columbia Accident Investigation Board

## Recommendation R7.5-1, R7.5-2, and R9.1-1

**R7.5-1** Establish an Independent Technical Engineering Authority that is responsible for technical requirements and all waivers to them, and will build a disciplined, systematic approach to identifying, analyzing, and controlling hazards throughout the life cycle of the Shuttle System.

The independent technical authority does the following as a minimum:

- Develop and maintain technical standards for all Space Shuttle Program projects and elements
- Be the sole waiver-granting authority for all technical standards
- Conduct trend and risk analysis at the subsystem, system, and enterprise levels
- Own the failure mode, effects analysis and hazard reporting systems
- Conduct integrated hazard analysis
- Decide what is and is not an anomalous event
- Independently verify launch readiness
- Approves the provisions of the recertification program called for in Recommendation 9.1-1

The Technical Engineering Authority should be funded directly from NASA Headquarters, and should have no connection to or responsibility for schedule or program cost.

**R7.5-2** NASA Headquarters Office of Safety and Mission Assurance should have direct line authority over the entire Space Shuttle Program safety organization and should be independently resourced.

**R9.1-1** Prepare a detail plan for defining, establishing, transitioning, and implementing an independent Technical Engineering Authority, independent safety program, and a reorganized Space Shuttle Integration Office as described in R7.5-1, R7.5-2, and R7.5-3. In addition, NASA should submit annual reports to Congress, as part of the budget review process, on its implementation activities.

## BACKGROUND

Prior to Space Shuttle return to flight (RTF), as called for in recommendation 9.1-1, NASA will develop a comprehensive plan with concrete milestones leading us to a revised organizational structure and improved management practices, and implementing *Columbia* Accident Investigation Board (CAIB) recommendations 7.5-1 through 7.5-3. Over the next several months, NASA will report to Congress our progress on development of options and milestones. The International Space Station (ISS) Program is a major participant in this process.

NASA is committed to changing the Agency's organizational structure to facilitate a culture that ensures that we can manage and operate our human space flight programs safely for years to come. Our organization's culture did not successfully embrace a

robust set of practices that promoted safety and mission assurance as priorities. As stated within the CAIB Report, "Cultural traits and organizational practices detrimental to safety and reliability were allowed to develop, including: reliance on past success as a substitute for sound engineering practices (such as testing to understand why systems were not performing in accordance with requirements/specifications); organizational barriers which prevented effective communication of critical safety information and stifled professional differences of opinion; lack of integrated management across program elements; and the evolution of informal chain of command and decision-making processes that operated outside of organization's rules."

Changing NASA's culture is a significant and critical undertaking. We must put in place structures and practices that continually emphasize the critical role of



safety and mission assurance while we adhere to sound engineering practices, and move toward a long-term cultural shift that values these practices. We must have the ability to search for vulnerabilities and anticipate risk changes. The character of our culture will be measured by the strength of NASA's leadership commitment to continuously improve safety and engineering rigor, and to share and implement lessons learned. This will allow us to improve safety by asking probing questions and elevating and resolving issues. Our culture must be institutionalized in an organizational structure that assures robust and sustainable checks and balances. The resulting organizational and cultural changes will balance the roles and responsibilities of Program management, technical engineering, and safety and mission assurance, while clarifying lines of authority for requirements. We must institutionalize an engineering quality and safety culture that will become embedded in our human space flight program even as personnel or organizations changes. This cultural transformation will require changes to the way we manage all of our programs, institutions, budgets, and human capital.

Although implementation will be as rapid as possible, we must take the time necessary to understand and address the risk posed by introducing changes into complex problems. As the CAIB Report states, "Changes in organizational structure should be made only with careful consideration of their effect on the system and their possible unintended consequences."

NASA is committed to assessing our options, understanding the risks, selecting the appropriate option, and implementing the needed change. We will dedicate the resources to accomplish these tasks.

## ISS PROGRAM IMPLEMENTATION

Recognizing the need to make significant managerial and organizational changes to address the deficiencies that led to the *Columbia* accident, NASA has already begun to implement a number of improvements. Guided by the CAIB Report, we will analyze and create an implementation strategy to ensure each of the CAIB's recommendations is met. The Office of Safety and Mission Assurance has been assigned as the focal point for this recommendation.

## STATUS

As a preliminary first step, based on the early recognition of the need for enhanced engineering and safety organizations, NASA recently established the NASA Engineer-

ing and Safety Center (NESC) at Langley Research Center to provide independent engineering and safety assessment. The NESC initiated operations in November 2003, and will further augment the Office of Safety and Mission Assurance's independent engineering and safety assessment capability. The NESC is a catalyst that will invigorate engineering excellence and strengthen the safety culture within NASA. The Headquarters Office of Safety and Mission Assurance will provide the NESC's budget and policy to assure independence. The NESC's charter includes, but is not limited to, the following:

- A centralized location for the management of independent in-depth technical assessments for safety and mission assurance, engineering, and the Shuttle and ISS Programs. This will be supported by expert personnel and state-of-the-art tools and methods.
- Independent testing to determine the effectiveness of problem resolutions or to validate the expected outcomes of models or simulations.
- Independent safety and engineering trend analyses.

The Agency has issued a Request for Proposal for the requirement to assist NASA in the transformation of the Agency's organizational and safety culture consistent with the findings of the CAIB. NASA seeks a proposal that will describe and lay out a framework for a comprehensive plan to develop and deploy an organizational culture change initiative within NASA, with an emphasis on safety culture and climate. This plan should provide for a systematic, integrated, NASA-wide approach to understanding prior and current safety climate and culture norms, diagnosing aspects of climate and culture that do not support the Agency's effective adoption of changes identified by the CAIB. We will develop a course or courses of action that will change behaviors and introduce new norms that will (1) eliminate barriers to a safety culture and mindset; (2) facilitate collaboration, integration, and alignment of the NASA workforce in support of a strong safety and mission success culture; and (3) align with, but not duplicate, current initiatives already under way in the Agency such as One NASA.

In addition, NASA is improving and strengthening current Shuttle and ISS Program management, engineering, and safety processes. However, the criticality of fully understanding all aspects of the CAIB recommendations requires a complete and thoughtful evaluation and response. These recommendations will result

in major organizational changes. NASA's priority is to fly safely while successfully executing our mission for the nation.

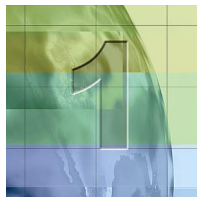
## FORWARD WORK

NASA is committed to making the organizational and cultural changes necessary to respond to the CAIB recommendations 7.5-1 and 7.5-2. The process of implementing and institutionalizing these changes will include investigating funding paths, determining requirement ownership, identifying Certification of Flight Readiness responsibility, and specifying responsibility within the human space flight enterprise for cost, schedule, and technical issues.

NASA has formed an interdisciplinary team, including representation from the ISS Program, to assess these issues to develop a detailed plan prior to RTF as required in recommendation 9.1-1.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Ongoing	Participate in Agency team developing enhanced engineering and safety capability



# **Columbia Accident Investigation Board**

## **Recommendation 7.5-3**

Reorganize the Space Shuttle Integration Office to make it capable of integrating all elements of the Space Shuttle Program, including the Orbiter.

### **BACKGROUND**

The complexities of the International Space Station (ISS) Program, including the International Partnering structure, on-orbit assembly and integration, and requirement for continuous operation and science research during assembly have necessitated a strong focus on integration since Program inception. As the ISS integrator, NASA has led the multilateral definition of integration processes that have governed ISS design, development, operation, and research capabilities. In addition, NASA integrates ISS transportation requirements across an international mix of space transportation systems (such as the Space Shuttle, Soyuz, Automated Transfer Vehicle, and H-II Transfer Vehicle). With NASA, the Boeing Company is responsible for system integration of the end-to-end Space Station. NASA recognizes that this diverse mix of organizational cultures and dependencies makes the Program integration function crucial to assuring ISS Program objectives are met, and all issues and anomalies are resolved in a timely manner.

NASA assures that all Program elements and associated contractors comply with the Program requirements and strategic objectives. With no precedent or blueprint for an international collaboration of this scale and complexity, NASA has evolved a centralized framework that integrates top-level decision-making across the partnership. In parallel, a decentralized framework at the worker level enhances communication and collaboration. Issue identification and resolution are integrated across teams and working groups that often include members separated by geography, time zones, language, and culture. This approach is key to early identification of potentially significant issues and provides multiple reporting outlets to senior managers: in real time up through the ISS Mission Management Team; or through the governing boards, Safety community, or ISS risk management process. NASA recognizes that effective communication is a critical factor in successfully executing the Program integration function.

### **ISS PROGRAM IMPLEMENTATION**

NASA has consolidated top-level technical integration functions in the ISS Program Integration Office. The Program Integration Control Board has decision authority to review and approve changes and actions at the ISS system level, and includes voting members from all major ISS organizations, Safety, the Engineering Directorate, Mission Operations Directorate, Space and Life Sciences Directorate, the Crew Office, and ISS contractors. The ISS Program Integration Office chairs the Multilateral Program Integration Control Board (MPICB) to address issues that affect more than one ISS Partner. In addition, joint ISS-Space Shuttle technical issues are reviewed at joint boards. The ISS Program Integration Office participates in these joint forums.

The Program Integration Office performs the classical systems engineering and integration (SE&I) function across multiple disciplines to assure overall integrated ISS functionality. The Program Integration Office performs SE&I assessments to optimize integrated vehicle performance, vehicle resources, external configuration, system architecture, and mission design. In addition, the office controls the top-level ISS specifications, interface control documents, and release drawings. A synergistic relationship among the NASA, International Partner, and contractor organizations that build, sustain, and operate ISS hardware enables NASA to effectively manage the end-to-end SE&I function.

NASA's contractor support is pivotal to successful implementation of the end-to-end SE&I function throughout the ISS life cycle by ensuring vertical integration of hardware and software teams and technical disciplines. In addition, horizontal integration across these multilateral teams and disciplines yields early identification and resolution of cross-functional and multi-mission problems, issues, and anomalies. As a result, complex on-orbit assembly and operations are demonstrated and validated preflight through detailed simulations, analyses, and integrated multi-element tests. Finally, the ISS senior managers along with the sponsoring technical experts scrutinize all findings and recommendations in

detailed preflight, flight readiness, and operational readiness review forums at predetermined intervals.

One example of an ISS integration activity is the Stage Integration Review. The Stage Integration Review team conducts early Program-wide reviews of ISS flight stages about 20 months prior to launch to ensure the initial operational procedures match Program needs and vehicle performance capabilities. NASA chairs a line-by-line bilateral or multilateral review, as required, of the designated flight's Assembly and Operations Support Plan. This exhaustive review has proven effective in identifying, amplifying, and then resolving "weak signals" that otherwise might have gone unnoticed. The ISS Program Manager chairs the final board.

At any point in the review processes, voting organizations can—and are expected to—halt the proceedings if a technical problem surfaces that indicates further investigation is required.

The Program Integration Office is also responsible for technical integration of future assembly elements to be provided by the European Space Agency, Japanese Aerospace Exploration Agency, Canadian Space Agency, and Russian Aviation and Space Agency (Rosaviakosmos). The MPICB reviews and approves technical integration decisions that affect two or more Partners. As a result of the Program's strong focus on multilateral integration, the unique on-orbit assembly of elements provided by the U.S, Russia, and Canada to date has been achieved successfully and without incident.

## STATUS

International integration processes and products ultimately feed the daily integration processes and products that facilitate manifest preparation, flight and increment management, and ISS operation. Multilateral analyses also are integral to NASA's ability to manage

crew timelines. NASA has reexamined and clarified interorganizational roles and responsibilities to ensure seamless transition of integration responsibilities. For example, with the completion of currently planned Russian elements, NASA has migrated the Russian Elements Office from Program Integration (development) to Mission Integration and Operations, an office with responsibility for integration of activities associated with on-orbit ISS operations.

## FORWARD WORK

Continually strengthen ISS Program integration functions and organizational responsibility as conditions warrant and contractual arrangements change.

A key Program integration objective is to achieve a smooth transition of tasks between contractors under the new contract consolidation strategy driven by the natural evolution from development to operational activities. For example, integration tasks previously performed by Boeing as the Prime contractor are transferring to new contractors. The challenge is to ensure no contractual barriers to impede integration across all contracts.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Nov 03 (Complete)	Transition from strategic to tactical integration
ISS Program	Nov 03 (Complete)	Clarification of inter-organization integration responsibilities
ISS Program	Dec 03 (Complete)	Complete contract consolidations



# ***Columbia Accident Investigation Board***

## ***Recommendation 9.2-1***

Prior to operating Shuttle beyond 2010, develop and conduct a vehicle recertification at the material, component, subsystem and system levels. Recertification requirements should be included in the Service Life Extension Program.

The underlying intent of this recommendation is addressed in Part 2.1, ISS Continuous Improvement Actions ISS-7 and ISS-8.



# Columbia Accident Investigation Board

## Recommendation 10.3-1

Develop an interim program of closeout photographs for all critical sub-systems that differ from engineering drawings. Digitize the closeout photograph system so that images are immediately available for on-orbit troubleshooting. [RTF]

### BACKGROUND

The nature of International Space Station (ISS) operations dictates that careful attention is placed on closeout imagery requirements in support of complex assembly operations, as well as on remote inspection and maintenance of ISS systems. Images are also used to support systems performance analyses and failure investigation. The ISS Program established the requirements to obtain images from hardware as it is built up into assemblies for launch. Lessons learned while operating the ISS for over five years have highlighted the importance of closeout imagery and led to strengthening of closeout imagery requirements and database management.

### ISS PROGRAM IMPLEMENTATION

To ensure safe and effective ISS operations, NASA requires that imagery records be maintained beginning with hardware manufacturing through on-orbit assembly, operations, and maintenance. The ISS Program uses preflight and closeout imagery to document the “as flown” configuration of the modules/elements and hardware that comprise the ISS.

Images are used to support remote maintenance and inspection of ISS systems. Images are exchanged between the crew and the ground in support of ISS systems maintenance and operation. The adequacy of on-orbit ISS imagery in support of ISS systems is discussed in response to R6.4-1.

Imagery is also used in real time to support assembly operations. All ISS assembly tasks are designed to ensure that adequate imagery is provided to the crew and ground.

In response to the *Columbia* Accident Investigation Board recommendations, this entire process was reviewed and found to be adequate.

### Imagery Management

The Imagery Working Group (IWG) is responsible for managing and integrating all imagery activities for the ISS. These activities include coordinating and developing imagery requirements for all customers; acquiring, distributing, and archiving ISS imagery; defining and procuring ISS imagery-related flight and training equipment; and resolving ISS imagery issues. The IWG consists of representatives across NASA and the ISS International Partners.

The ISS Program has a dedicated database, the Digital Imagery Management System (DIMS), containing preflight and closeout images as well as on-orbit images. Engineering and logistics cataloging data are submitted with preflight closeout imagery to increase the search capability of the database. Imagery is retrievable from the DIMS upon demand. In addition, the Video Asset Management System (VAMS) database contains all preflight, downlinked, and returned ISS video.

A complete imagery record of the integrated ISS configuration and crew assembly activity is maintained. These requirements are documented in SSP 50261-01, *Generic Ground Rules, Requirements and Constraints, Part 1: Strategic and Tactical Planning*. This record is required to support planning for assembly and maintenance, training of crewmembers, and failure analysis. It includes imagery to support the following important ISS functions:

1. Ensure the safety of the on-orbit crew and vehicle.
2. Support the successful assembly, maintenance, operations, and utilization of ISS, including preflight and closeout imagery.
3. Document the configuration and monitor the overall condition of ISS.
4. Evaluate the performance of the vehicle and space operations.

5. Support problem solving and troubleshooting of assembly, maintenance, operations, anomaly, and contingency functions.
6. Document crew activity (internal and external to ISS) and Earth observation.
7. Provide information about ISS activities to educational outlets, the public, and national and international media sources.

The following provides descriptions of each functional area. The procedures and processes, technical as well as managerial, associated with each of these functional areas were assessed and considered adequate.

### Preflight Closeout Imagery

The ISS Program uses preflight closeout imagery to document the “as flown” configuration of the modules/elements and hardware that comprise the ISS. This imagery is primarily used to support planned and unplanned on-orbit maintenance, crew training, procedure development, and sustaining engineering. Hardware providers and mission operation organizations create preflight imagery requirements. Preflight imagery for ISS hardware is acquired for the U.S. segment as well as for International Partner-provided hardware. Imagery is submitted with sufficient cataloging data to make it retrievable in the DIMS. This preflight imagery is used for analysis to determine the on-orbit condition of the hardware.

Primary and secondary structures, wire harnesses, fluid lines, connectors, rack buildup, and interfaces to the module document the layered construction of the hardware in context. Orbital replacement units (ORUs) are spares for planned on-orbit maintenance; they are imaged before, during, and after integration, with emphasis on crew interfaces. The exterior of the module is mapped by location code, specifically the ORUs, translation paths, and workstations.

The Preflight Imagery Plan (PFIP) contains ISS imagery requirements to document configuration of the hardware. The hardware provider submits the PFIP to the ISS Program. System experts and imagery users review and modify the PFIP requirements as necessary. Individual PFIP requirements are traceable to the images in DIMS that satisfy those requirements. These images are available on line to support flight operations. Currently, the DIMS contains more than 75,000 closeout images that satisfy PFIP requirements through flight 7Soyuz. The International Partners supply an imagery plan at launch

minus 24 months that responds to ISS Program requirements to ensure adequate photographs and cataloging of international hardware.

Specifically, at the Kennedy Space Center (KSC) Space Station Processing Facility, ISS closeout imagery is acquired based on procedures that are documented in Boeing Standard Practice SP-QUAL-002, *ISS Configured for Test*, and in Boeing SPP-016, *Standard Practice and Procedures*. The acquired closeout imagery is placed in the official ISS DIMS imagery database.

### On-orbit Operations

ISS Program participants may require acquisition of specific images to support on-orbit operations, such as routine maintenance or capturing a series of images for media purposes. Detailed ISS on-orbit imagery requirements are defined in the Increment Definition and Requirements Document (IDRD), Annex 3, which includes the integrated on-orbit imagery requirements for each flight and increment stage. These requirements are used to develop the imagery Operations Data File (ISS Photo/TV procedures) and the operations timelines, crew training plans, and imagery distribution requirements.

Any planned on-orbit hardware reconfiguration is documented in Annex 3 and requires closeout imagery. Unplanned on-orbit reconfiguration of the hardware is documented and implemented with written procedures that require closeout imagery of the completed configuration changes. When required, this imagery is then used to update engineering drawings.

### Ground Operations

The Johnson Space Center (JSC) Mission Operations Directorate Photo/TV group provides integrated imagery task instructions to ISS crews. This includes video system training necessary to acquire high-quality imagery, in-flight Photo/TV procedures, and flight execution as well as electronic still photography and video downlink training. Real-time mission support is provided through the flight control team under the leadership of the flight directors. After every flight, any techniques and processes determined needed to improve tasks are implemented.

The Information Resources Directorate at JSC is responsible for the reception, processing, retention, and distribution of video and still imagery acquired on board the ISS. Downlinked imagery, transmitted from either the Space Shuttle or the ISS, is received at the Mission

Control Center via the Space to Ground Network. It is then transmitted to the JSC Video Control Center or the Digital Imaging Laboratory. There the imagery is recorded, cataloged, archived, and distributed, per ISS Program requirements. Imagery is available through request to the Public Affairs Office.

The JSC Image Science and Analysis Group (IS&AG) provides analyses and assessments of the ISS from the photographic and video imagery acquired from ISS- and Shuttle-based cameras. Image analysis personnel use the Video Digital Analysis System to provide a full range of imagery processing, enhancement, and analysis services in support of ISS troubleshooting and problem solving, assembly, maintenance, vehicle performance, operations, anomalies, and contingencies. The ISS Mission Evaluation Room directs, in real time, the IS&AG support for troubleshooting and anomaly analysis. A wide range of other analyses, such as appendage motion studies, docking performance, and vehicle configuration, is performed at the direction of Engineering, Mission Operations, or the ISS Program. IS&AG sponsors the ISS External Survey, a periodic inspection of the ISS exterior to detect and assess damage or changes over time. The images from these surveys are analyzed and, if inadequate, higher-fidelity images are obtained via other on-board cameras or improved viewing angles.

## FORWARD WORK

The ISS preflight imagery process has been in place for five years and has evolved into a mature process. The imagery format has evolved from 35mm film to digital high-resolution format. Digital technology is constantly being researched to apply to preflight and other ISS

imagery. For example, the ISS Program is actively prototyping high definition television downlink for future use on ISS.

Preflight imagery for International Partner modules being integrated and processed at KSC will be acquired per existing requirements. Additionally, ongoing reviews of the preflight imagery plans are performed to assure that all future modules/hardware are fully compliant with ISS Program imagery requirements.

The ISS Program is studying improvements in the process used to capture differences between on-orbit configuration and the engineering drawings (ref. Recommendation R10.3-2) and whether additional on-orbit imagery is required. The IWG is also actively involved in the certification and deployment of a digital extravehicular activity still imagery camera to enhance on-orbit surveys and inspections of the ISS and the Shuttle during docked operations.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Complete	Process review for adequacy
ISS Program	Ongoing	Evaluate digital on-orbit imagery capabilities





# **Columbia Accident Investigation Board**

## **Recommendation 10.3-2**

Provide adequate resources for a long-term program to upgrade the Shuttle engineering drawing system including

- Reviewing drawings for accuracy
- Converting all drawings to a computer-aided drafting system
- Incorporating engineering changes

### **BACKGROUND**

The International Space Station (ISS) continues to be designed, developed, manufactured, and operated by many organizations from around the globe. The nature of ISS dictates that careful attention is placed on development, control, and rapid access to engineering data (i.e., drawings). With this in mind, NASA's strategy from ISS initiation was to develop and implement an electronic drawing system.

Detailed drawings of International Partner hardware are maintained by the International Partners. Agreements allow the necessary information to be available for all Partners in support of operations and on-orbit anomaly resolution.

### **ISS PROGRAM IMPLEMENTATION**

ISS drawings reside in the Vehicle Master Data Base (VMDB). The VMDB has been in operation since 1995. It is a centralized repository that provides ISS with engineering and operations drawings and data. Also, it provides access to view and print engineering drawings, associated lists, parts lists, and engineering orders.

The VMDB drawings interface is presently the most widely used feature of the VMDB. VMDB drawings are accessible and available to all Program participants. Examples include:

- The Mission Evaluation Room and the Engineering Support Room use VMDB for sustaining engineering and real time operations.
- The Vehicle Integrated Performance and Resources team uses VMDB to perform resource analysis and allocation.
- The Mission Operations Directorate uses VMDB for flight operations and ISS operations.

- The Manifest Working Group uses VMDB as a tool to assist in the formulation and delivery of the Program Approved Manifest and Planned Manifest.

Shortcomings in the completeness and retrieval of drawings from the VMDB have necessitated several improvement efforts. The database is migrating to another software application known as the Electronic Document Management System (EDMS) to improve retrieval processes. While drawings continue to be added, audits of database processes and completeness have been initiated.

### **STATUS**

To date, there are approximately 80,000 drawing entries, including 49,000 unique drawings with their revisions. Released engineering data, including drawings and advanced engineering orders, continue to be loaded daily from different ISS Program release systems into the VMDB. Government-furnished data, International Partner (to a higher level), and subcontractor drawings continue to be delivered and loaded. ISS on-orbit stage drawings are being delivered and loaded on a regular basis.

An initial audit of the VMDB has found that it is missing data and drawings and lacks rigorous configuration management. In addition, the VMDB has identified a backlog and a number of missing drawings that need to be located and loaded into VMDB.

### **FORWARD WORK**

Portions of the VMDB, which are in portable document format (.pdf), are currently being integrated into the new EDMS. With this tool, integration of documents from different sources will be accomplished in the near future.

A process audit will be conducted of VMDB. Updates to refine the current process will be identified and refined to ensure that missing/backlog of drawings are captured in the future. This audit will also include an assessment of the tool's user friendliness and ability to access data on a timely basis.

The ISS Program will perform an assessment of the current data/drawings being loaded into VMDB and reassess the scope of data/drawings that are being loaded into VMDB. This will include a review of the government-furnished equipment and International Partner drawings and data that are not currently required to be delivered. The results of this review will be applied to the EDMS.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Dec 03 (Complete)	VMDB integration to EDMS and initial activation and user access
ISS Program	TBD	Follow-on audit complete
ISS Program	Ongoing	Load backlog/missing drawings



## **Part 2**

# **International Space Station Continuous Improvement Actions**

*This section details specific actions that the International Space Station (ISS) Program has undertaken as a result of (Part 2.1) Continuous Improvement Actions, (Part 2.2) formal observations of the Columbia Accident Investigation Board (CAIB), and (Part 2.3) supplemental recommendations/observations made by General Deal in Volume II of the CAIB Report.*

*Within hours of the Columbia tragedy, the ISS Program formed teams to review the requirements, potential hazards, and risks associated with maintaining a continued crew presence on ISS with no Space Shuttle support. This comprehensive effort reviewed areas such as on-board availability of consumables and spare parts, hardware lifetime and certification issues, and capabilities for supporting ISS and its crew with only Russian Progress and Soyuz vehicles. All ISS Partners agreed to the strategies necessary to continue with crewed operation of the ISS.*

(Continued on back)



*Over time, the ISS Program Manager initiated several actions to assess our overall risk posture in the current situation. An effort was made to reassess previous decisions to accept risk in light of observed performance of the ISS on orbit and the changes in plans from when risk was accepted. The reviews were done with the CAIB Report in mind and its mandate to avoid the trap of being lured into thinking that low-probability events will not happen simply because they have not happened in the first few years of ISS operations.*

*Future updates to the ISS Continuing Flight Plan will expand Part 2 to include additional suggestions from various sources. This will ensure that beyond returning safely to flight, we are institutionalizing sustainable improvements to our culture and programs that will ensure we can meet the challenges of continuing to expand the bounds of human exploration.*



## Part 2.1

# International Space Station Continuous Improvement Actions

*Program teams were asked to review the entire list of Program-approved items (waivers, deviations, exceptions, etc.) that identified significant risk. The teams applied two major tests: (1) Had changes in the Program or the performance of the Space Station on orbit significantly changed the context of approval of individual items; and (2) Did the items in aggregate introduce significant additional risk that was overlooked as the items were approved individually. The experts most knowledgeable about the item were involved in the evaluation. Once these risk areas were initially identified and assessments were initiated, they became ISS Program Continuous Improvement Actions to indicate that the Program had gone above and beyond the recommendations of the CAIB Report.*

*Part 2.1 describes the actions and the current status of each Continuous Improvement Action.*





# ISS Continuous Improvement Actions

## *ISS Continuous Improvement Action 1*

The ISS Program will review all Program waivers, deviations, and exceptions for validity and acceptability.

### BACKGROUND

The International Space Station (ISS) Program process for granting waivers, deviations, or exceptions is based on a system risk assessment of the specific inability to meet the requirement. If the risk assessment shows adequate risk mitigation actions are in place to prevent any serious consequence, the risk mitigation is granted. These exemptions are formally tracked and reviewed anytime a flight activity could be adversely affected.

### ISS PROGRAM IMPLEMENTATION

Because waivers, deviations, and exceptions to ISS Program requirements contain the potential for unintended risk, the ISS Program has directed all elements to review these exemptions to Program requirements to determine whether the exemption is still valid in light of five years of on-orbit ISS operational experience. In addition, the ISS Program will evaluate the exemptions to assess whether the totality of exemptions carries additional risk. Particular attention is being placed on the exemptions that carry safety risks of a catastrophic nature with a short time to effect.

There are currently over 700 waivers, deviations, and exceptions to ISS Program requirements. The task of reviewing these exemptions is being executed in two phases.

Phase 1: Each waiver, deviation, and exception will be reviewed by ISS Program personnel under the auspices of the appropriate Program control board based on the following ground rules:

1. Determine if risk posture has changed in light of the *Columbia* tragedy or since observed operation of the ISS.
2. Determine if modifications should be considered to the vehicle or the requirements in light of a changed risk posture.
3. If the same requirement impacts several deviations/waivers/exceptions, review whether the requirement should be changed.

4. Review the waivers, deviations, and exceptions for cumulative risk due to an accumulation of accepted risk over time.

Phase 2: The ISS has created a team of ISS system experts to look at each of the items not judged to have a previous disposition as valid or overcome by events. This team has been tasked to develop an in-depth risk assessment for potential impacts to the ISS. This team consists of representatives of the ISS program offices, Mission Operations, Flight Crew, Johnson Space Center (JSC) Safety, Boeing, and JSC Engineering's Chief Engineer office.

Further, this team will review the cumulative impacts of each of these approved exemptions to overall ISS risk. The team is tasked to review the exemptions from an integrated system approach and to look for interdependencies between individual exemptions. The risk assessments and mitigation plans will be tracked in the ISS Risk Management system. Status will be reported to the ISS Program Manager.

### STATUS

Phase 1 review and categorization of the waivers, deviations, and exceptions has been completed, and the Phase 2 assessment is nearing completion. Previously reported preliminary categorizations and counts are being altered based on additional analysis since Phase 1. Current efforts are compiling these results for disposition by Program management.

In addition to the above exemptions, the ISS Program reviewed the following:

- Criticality 1 Software Program Notes (SPNs). SPNs are notes documenting problems or operational issues with Program software. SPNs have been reviewed and, where appropriate, have been assigned for closure in future releases of ISS software.
- Waivers to the Generic Ground Rules and Constraints document. While each of these waivers is considered to be valid or overcome

by events, activities have been initiated to determine whether changes can be made to operational plans to eliminate the need for these waivers.

- KSC processing requirements exemptions: A senior technical board was established to review these exemptions and the activities of this board. To date, only one item has been found that needs further review and analysis.

In addition, the JSC Safety and Mission Assurance (S&MA) organization has been performing an independent review of all of the waivers, deviations, and exceptions. The S&MA organization is nearing completion of this review.

### FORWARD WORK

Finish the review and categorization of all waivers, deviations, and exceptions. Complete the in-depth team

review and analysis to identify any technical items requiring further work. Current efforts are compiling the results of these reviews for disposition by Program management.

Also, efforts continue to develop a plan for how a standard review of waivers, deviations, and exceptions can be incorporated into the standard ISS Program processes.

### SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Dec 03 (Complete)	Phase 1 review of waivers, deviations, and exemptions
ISS Program	Mar 04	Complete Phase 2 review
ISS Program	Apr 04	Report results to ISS Program Manager





# ISS Continuous Improvement Actions

## *ISS Continuous Improvement Action 2*

The International Space Station Program will review all hazard report non-compliances, regardless of classification, to review rationale for acceptance of these “accepted risks.”

### BACKGROUND

International Space Station (ISS) safety analysis is accomplished by performing a top-down assessment of hazards and identifying the events that could lead to those hazards. The results of these analyses are captured in hazard reports. The ISS Program has established safety requirements designed to provide the necessary control of hazards. The highest safety risk to the ISS and its crew is represented by a failure to meet ISS safety requirements. For environmental- or operational-induced risks, hazard reports are prepared. When a safety requirement is not met and the ISS Safety Review Panel feels that the risk is adequately controlled, a noncompliance report (NCR) to the hazard report is generated to justify and accept the risk. As a result of the *Columbia* accident, the ISS Safety Review Panel (SRP) conducted a review of each NCR to determine whether the ISS Program should revisit the associated accepted safety risks. This activity reviewed assumptions and ground rules used when the NCR was accepted to assess whether they were still valid. Many steps were taken to provide a level of confidence on how the original NCRs compare to the current ISS conditions and operations. This assessment has been completed, and this summary briefly describes those steps and provides the results of the assessment.

### ISS PROGRAM IMPLEMENTATION

The ISS SRP identified several potential sources of ISS changes that could have impacted the NCR assumptions. These areas included how the current ISS environment compares to the assumed environment when the NCR was approved; how the current ISS operations compare to the operations assumed when the NCR was approved; additional data that would question the validity of the rationale on the NCR; how ground test or on-orbit anomalies may have weakened the assumptions of the strength of some of retention rationale features; and any changes in detectability of failures that could contribute to the hazard manifesting itself since the NCR was originally approved. These criteria were used to assess each existing ISS NCR.

Ground rules were established to limit the review of NCRs to those carrying the greatest amount of Program risk and affected by anomalous performance. For example, NCRs addressing the control of touch temperatures were not reassessed because the associated risks are well managed with operational controls. On-orbit anomalies with safety implications were reviewed to see if they had any impact on NCRs. The decision to limit the review of anomalies to on-orbit anomalies was based on the fact that most ground test failures result in restoration of function or design back to compliance with the specifications and drawings.

NCRs impacted by the defined criteria were categorized as follows:

1. No Significant Impact – No changes/action required
2. Minor Impact – Recommend NCR update and subsequent OSB NCR re-approval/signature
3. Major Impact with Acceptable Risk Mitigation – Recommend rewrite of NCR with subsequent full panel review and re-approval
4. Major Impact with Potentially Unacceptable Risk – Reopen NCR and go to full SRP for proper action assignments to resolve

It was determined that one NCR had “Major Impact with Potentially Unacceptable Risk.” The NCR addressed a Space Shuttle failure mode that could affect the ISS. Specifically, the Space Shuttle Reaction Jet Driver does not have adequate failure tolerance to control against an inadvertent Space Shuttle Orbiter primary jet firing. The ISS SRP determined that the hazard exposure was greater than was considered at the time of acceptance of the NCR and asked that the Space Shuttle and ISS Programs revisit this issue. This work has been initiated.

Not specifically covered by an NCR, yet considered very important by the ISS SRP, is the ISS external Thermal Control System robustness to failure situations. In response to this concern, the ISS Program initiated development of

electrical power jumpers that remove the risks associated with certain external thermal system failures.

Four NCRs had “Major Impact with Acceptable Risk Mitigation.” These included three Russian Segment micrometeoroid and orbital debris NCRs, for which Russian delays in implementing enhanced protection have occurred. Together with our Russian partners, the ISS Program has taken steps to mitigate these risks. One NCR addressed a system issue that has since been resolved.

## STATUS

In response to the changed risk posture identified by this review, the ISS Program has taken concrete action to mitigate risks.

## FORWARD WORK

All NCRs will be updated to accurately reflect the risk being accepted by the ISS Program. The SRP will review all revised NCRs for concurrence.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Sep 03 (Complete)	Completed NCR Review
ISS and Shuttle Programs	Under Review	Agree on risk mitigation plan for Shuttle Reaction Jet Driver hazard



# ISS Continuous Improvement Actions

## *ISS Continuous Improvement Action 3*

ISS will review its Certification of Flight Readiness (CoFR) process and identify areas for improvement.

### BACKGROUND

The International Space Station (ISS) Certification of Flight Readiness (CoFR) process enables certification of the safety and operational readiness of the ISS Program hardware, software, facilities, and personnel that support prelaunch activity, launch, return, on-orbit assembly, operations, and use of the ISS. Additionally, the CoFR process enables the assessment and certification of the successful completion of activities that are required to ensure mission success. Certifying organizations (ISS Program contractors, International Partners and Participants, ISS Program organization managers, and other NASA institutional managers) use the CoFR process to provide endorsements to the ISS Program prior to committing to flight and continued ISS operations.

### ISS PROGRAM IMPLEMENTATION

The ISS Program formed a team to assess the adequacy of its CoFR process and to make recommendations for improving the way we review the risks accepted when committing to flight and continued operation of the ISS. This assessment included a process review, a documentation review, and an audit of the key processes used by certifying organizations in making their endorsement decisions. In addition, the ISS Program requested that a representative of the Independent Assessment Office (IAO) work with the ISS Program review team and provide an independent assessment of the team's work and of the CoFR process itself.

### STATUS

ISS Program management received and reviewed initial recommendations from the CoFR team in early September 2003. This early release of important findings allowed the ISS Program to implement several improvements in time for the Stage Operations Readiness Review (SORR) and Flight Readiness Review (FRR) that were conducted in preparation for the launch of the Expedition 8 crew on ISS flight 7Soyuz. Specific changes included additional guidance on the content of CoFR review presentations, with an increased focus on the risks associated with operations and hardware flown for the first time. This process was successfully executed

during the 7Soyuz SORR and FRR as all Program elements fully discussed concerns surrounding the ISS environmental monitoring capability. When concerns with the adequacy of ISS environmental monitoring were brought to the SORR, these concerns were openly discussed and actions were put in place to ensure that all possible steps to mitigate the risk were taken. The concerns and mitigating actions were fully discussed at the FRR, where NASA management decided to proceed with the launch of the Expedition 8 crew.

The NASA IAO provided an initial report on the CoFR process to the ISS Program, and this report was consistent with the observations of the ISS Program Review Team.

The ISS Program Review Team provided their initial report in November 2003. In mid-January 2004, the Space Station Program Control Board (SSPCB) approved the following phased plan for additional changes to the ISS CoFR process document (SSP 50108). Phase 1 of this plan was completed prior to the SORR for ISS flight 13Progress.

Phase 1 – Update CoFR board membership to incorporate roles of three new contractors, revisions to reflect organizational realignments of existing support groups, and terminology definitions for risk and standard/forward work.

Phase 2 – Resolve IAO CoFR process concerns, refine/clarify processes, and include updates to implementation plans of support organizations.

Phase 3 – Address and resolve CoFR management and logistics (e.g., control of implementation plans of support organizations, CoFR staff support).

### FORWARD WORK

The ISS Program will continue to review the recommendations of the IAO and its own CoFR review team. It will also assess the conclusions and changes of the Space Shuttle Program for potential ISS applicability.

The ISS Program is committed to implementing the recommendations of the ISS Program review team and the IAO. The ISS Program has assigned the ISS Mission Integration and Operations Office the task of responding to each of the recommendations.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Sep 03 (Complete)	Initial recommendations
ISS Program	Oct 03 (Complete)	IAO Phase 1 Report

Responsibility	Due Date	Activity/Deliverable
ISS Program	Nov 03 (Complete)	Program Review Team Phase 1 Report
ISS Program	Jan 04 (Pending)	SSPCB-approved SSP 50108 updates to support 13Progress
ISS Program	Feb 04	SSPCB disposition Program Review Team and IAO recommendations
ISS Program	TBD	Complete review of Shuttle CoFR changes for ISS applicability



# ISS Continuous Improvement Actions

## *ISS Continuous Improvement Action 4*

The International Space Station (ISS) Program has initiated a review of its critical items lists (CIL) and the failure modes and effects analyses (FMEA) associated with the CIL to revalidate acceptance rationale based on experience gained in operating a crewed ISS for almost 3 years.

### BACKGROUND

The failure modes and effects analysis/critical items list (FMEA/CIL) is used to identify potential hardware failure modes and their credible causes, and to assess their worst-case effect on International Space Station (ISS) operations and crew/ISS survival. A subset of the hardware analyzed in the FMEA is categorized as a critical item based on the risks from failure and the corresponding criticality classification assigned. For these critical items, acceptance rationale is documented that minimizes the failure probability and/or precludes the failure effect.

As part of the ISS design process, the ISS Program performed the following steps:

1. Developed an FMEA on all ISS hardware to identify critical items.
2. Identified essential manufacturing inspection and test processes for critical items to eliminate or further reduce the risk. Consideration is given to enhancing the hardware design by focusing on design specification, qualification, and acceptance requirements.
3. Formulated operational and maintenance procedures for critical items to eliminate or minimize the likelihood of occurrence and the effect associated with each failure mode.
4. Formally documented the acceptance rationale identified for each failure mode in the CIL retention rationale and provided assurance that the critical item controls are effectively implemented.

### ISS PROGRAM IMPLEMENTATION

The ISS Program Reliability and Maintainability (R&M) Panel review is revalidating all ISS critical items using the following process:

1. Reviewing criticality assignments for accuracy and consistency with current use and environment.

2. Validating the retention rationale associated with each critical item to ensure that the level of risk initially accepted by the ISS Program has not changed.
3. Establishing new or modifying existing retention rationale, as required.
4. Capturing any on-orbit or ground processing experience that has impacted the CIL retention rationale.
5. Developing or revising FMEA/CIL worksheets to include updates.
6. Submitting updated FMEA/CIL worksheets for approval to the R&M Panel.
7. Submitting revised or newly identified critical items for approval to the Safety and Mission Assurance (S&MA) Panel and, if required, the Space Shuttle Program Control Board (SSPCB).

The R&M Panel process includes categorizing its findings into three types: High, Medium, and Low. High represents technical issues and open work to the retention rationale. Medium represents minor documentation issues. Low represents no impact to the critical item. The ISS Program subsystem teams will participate in this effort by reviewing findings with the R&M team. The ISS R&M Panel will serve as the responsible forum for managing completion of these tasks.

### STATUS

Each ISS critical item was submitted to and reviewed by the S&MA subsystem engineers (SSEs). The S&MA SSEs generated numerous comments. A few High category comments were identified and are being validated by the subsystem teams. The majority of the comments, however, are categorized as Medium (i.e., minor documentation issues). For instance, updates to retention rationale are required to incorporate failures experienced subsequent to approval of the CIL. All technical comments requiring concurrence from the ISS

Program SSEs are being provided to the subsystem teams for their review and approval.

### FORWARD WORK

Revised critical items will be brought to the S&MA Panel and the SSPCB for approval, as required. Should any of the revised critical items be disapproved for Program acceptance, the ISS Program will assess hardware or process changes. The ISS Program will ensure that a process is in place to review and update any ISS FMEA/CIL as the need arises through the life of the ISS.

### SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS R&M Panel	Nov 03 (Complete)	Status Report to Program Manager
ISS R&M Panel	Nov 03 (Complete)	S&MA SSE Critical Item Review
ISS R&M Panel	Feb 04	ISS Subsystem Team Review
ISS R&M Panel	Mar 04	Approval of revised FMEA/CIL Documentation
SSPCB	As Required	SSPCB disposition



# ISS Continuous Improvement Actions

## ISS Continuous Improvement Action 5

Review ISS anomaly resolution processes to ensure that proper requirements are in place and anomaly resolution processes are operating effectively.

### BACKGROUND

An “anomaly” is any unexpected performance characteristic or condition that requires further investigation. A “nonconformance” is any anomaly where one or more characteristics do not conform to requirements specified in a contract, bilateral agreement, drawings, specifications, etc. The proper identification, investigation, resolution, reporting, trending, and documenting of International Space Station (ISS) hardware, software, and operations anomalies, whether they occur on the ground or on orbit, is essential in assuring successful activation and operation of ISS systems. The integration of numerous International Partner, NASA, and contractor systems and organizations, coupled with the fact that it may not always be feasible to return anomalous hardware to the ground for investigation or repair, are some of the primary reasons that anomaly investigation and resolution is one of the most critical, complex, and challenging ISS Program processes.

Throughout the design, development, testing, and delivery of ISS systems, Space Station Program (SSP) document SSP 41173, *Space Station Quality Assurance Requirements*, required that all NASA ISS contractors and hardware/software providers establish formal processes for identifying, investigating, resolving, and documenting nonconformances. SSP 30223, *Problem Reporting and Corrective Action [PRACA] Requirements for Space Station Program*, defined which nonconformances had to be elevated from a provider’s reporting system to the ISS Program and, once elevated, how the ISS Program was to investigate and disposition those nonconformances. System Problem Resolution Teams (SPRTs) consisting of engineering, Safety and Mission Assurance/Program Risk (S&MA/PR), operations, and other organizations were then established for each system to investigate and resolve those reportable nonconformances.

As the ISS Program began to transition from designing, building, testing, and delivering systems to launching, activating, operating, and sustaining systems, it also continued to evolve its anomaly resolution processes. SSP 41173 has continued to evolve to better define

expectations of government and contractor reporting, investigation, and Material Review Board (MRB) disposition of anomalies that occur on the ground during the development and testing of ISS systems, hardware, and software. SSP 30223 was updated to require that the ISS PRACA process and associated database become the on-orbit hardware nonconformance reporting system and that all on-orbit nonconformances be treated in the same manner as those ground nonconformances elevated to an SPRT by a contractor or hardware provider. The ISS Mission Evaluation Room (MER) also created the Item for Investigation (IFI) process and database to track all on-orbit anomalies until they could be confirmed as reportable nonconformances and documented in the appropriate PRACA database.

In addition, Management Directive MGT-OA-019, *On-Orbit Anomaly Resolution Process*, was released to formally define the implementation process for how on-orbit system anomalies, as well as non-system anomalies with potential system or crew safety impacts (e.g., payloads), should be reported, investigated, and dispositioned.

While MGT-OA-019 recognized that the ISS Flight Director was responsible for taking any immediate actions required to protect the ISS and its crew, it also established the ISS MER as the primary organization responsible for investigating on-orbit system anomalies and identifying appropriate corrective actions to allow safe and extended operations until the anomaly could be fully resolved. The directive also established criteria and guidelines for transitioning responsibility for continuing the root cause investigation and implementation of long-term corrective actions and recurrence controls from the ISS MER to the SPRTs once the “real-time” and “near-real-time” risks were mitigated.

Similar to the system community’s efforts to evolve the on-orbit anomaly reporting and disposition process, the ISS Payloads Office established similar processes for the investigation and functional disposition of on-orbit anomalies involving NASA payloads and scientific research. Those processes established the Payload Operation Integration Center (POIC) and its Payload

Operations Director as the primary organization responsible for initially investigating and resolving on-orbit payload anomalies and for assuring that any anomalies that could potentially result in interface or integration impacts upon other NASA or Partner systems were communicated to and worked with the Flight Control Team, ISS MER, and SPRTs, as appropriate.

Figures ISS-5.1 and ISS-5.2 illustrate the complexity of the integrated ground and on-orbit anomaly resolution processes as defined and required by SSP 30223 and MGT-OA-019.

## ISS PROGRAM IMPLEMENTATION

In January 2003, the ISS Program established a process improvement team to evaluate the overall effectiveness of the ISS on-orbit anomaly resolution processes, as well as the integration of those processes with other critical ISS processes (e.g., waivers, change requests). The team was also asked to recommend corrective actions to resolve those deficiencies, to determine where improvements could be made by integrating different anomaly resolution processes and/or tools (e.g., systems and payloads; ISS and Shuttle), and to monitor the effectiveness of any implemented corrective actions.

Following the STS-107 accident in February 2003, the team also increased its level of participation and coordination with the Space Shuttle Program return to flight team assessing the Shuttle Program's anomaly resolution process.

It was decided to initially focus the team's evaluation on the government's process for evaluating and dispositioning all on-orbit hardware anomalies, as well as those ground anomalies that could not be dispositioned within the scope of the MRB processes used by the various ISS contractors. Deferring assessment of the effectiveness of the various contractor quality assurance processes was considered appropriate since audits of these processes are performed when a contractor is selected. In addition, the S&MA/PR Office has contracted with the Defense Contractor Management Agency to provide quality assurance oversight at the various contractors. As part of its efforts associated with ISS Continuous Improvement Action ISS-12, the S&MA/PR Office is determining the need to make changes in its formal contractor surveillance audit process.

The team's evaluation identified several strengths and deficiencies that were reported to ISS Program management via the Systems Working Group (SWG) between

February and May 2003. SWG is a multi-organizational forum where integrated system and process issues may be discussed.

As a result of the SWG discussions, ISS Program management approved several corrective actions and their associated implementation schedule. These same strengths and deficiencies, as well as the status of on-going corrective action efforts, were also reported to the Space Station Program Control Board in September 2003, with periodic updates being presented as certain milestones are achieved or changed.

The reported strengths, deficiencies, and ongoing corrective actions and improvements are described below.

### Strengths

The seven anomaly resolution process strengths identified by the continuous process improvement team are as follows:

- S1. The on-orbit portion of the anomaly resolution process for ISS systems, including the interfaces between and roles and responsibilities of the ISS MER, flight control team, SPRTs, and other ISS Program organizations, is well defined within ISS Program-level work instructions.
- S2. On-orbit anomaly information is immediately and consistently disseminated and frequently presented to all levels of ISS Program management, with requirements for dissemination clearly established within ISS Program-level work instructions.

For example, all anomalies that occurred within the previous 24 hours are reported to the ISS Mission Management Team (IMMT) chairperson and/or IMMT on a daily basis; to ISS Vehicle Office management, system managers, and ISS Chief Engineering personnel during daily management teleconferences; to ISS and Headquarters S&MA personnel on a daily basis via the ISS MER S&MA Console's Daily Shift Report; to the operations community via the flight control teams Daily Spacecraft Analysis report; and throughout the ISS and Headquarters community via the daily Increment Management Center report. In addition, the status of open on-orbit anomalies and associated resolution activities is presented to the appropriate ISS Program Boards on a periodic basis (e.g., weekly).



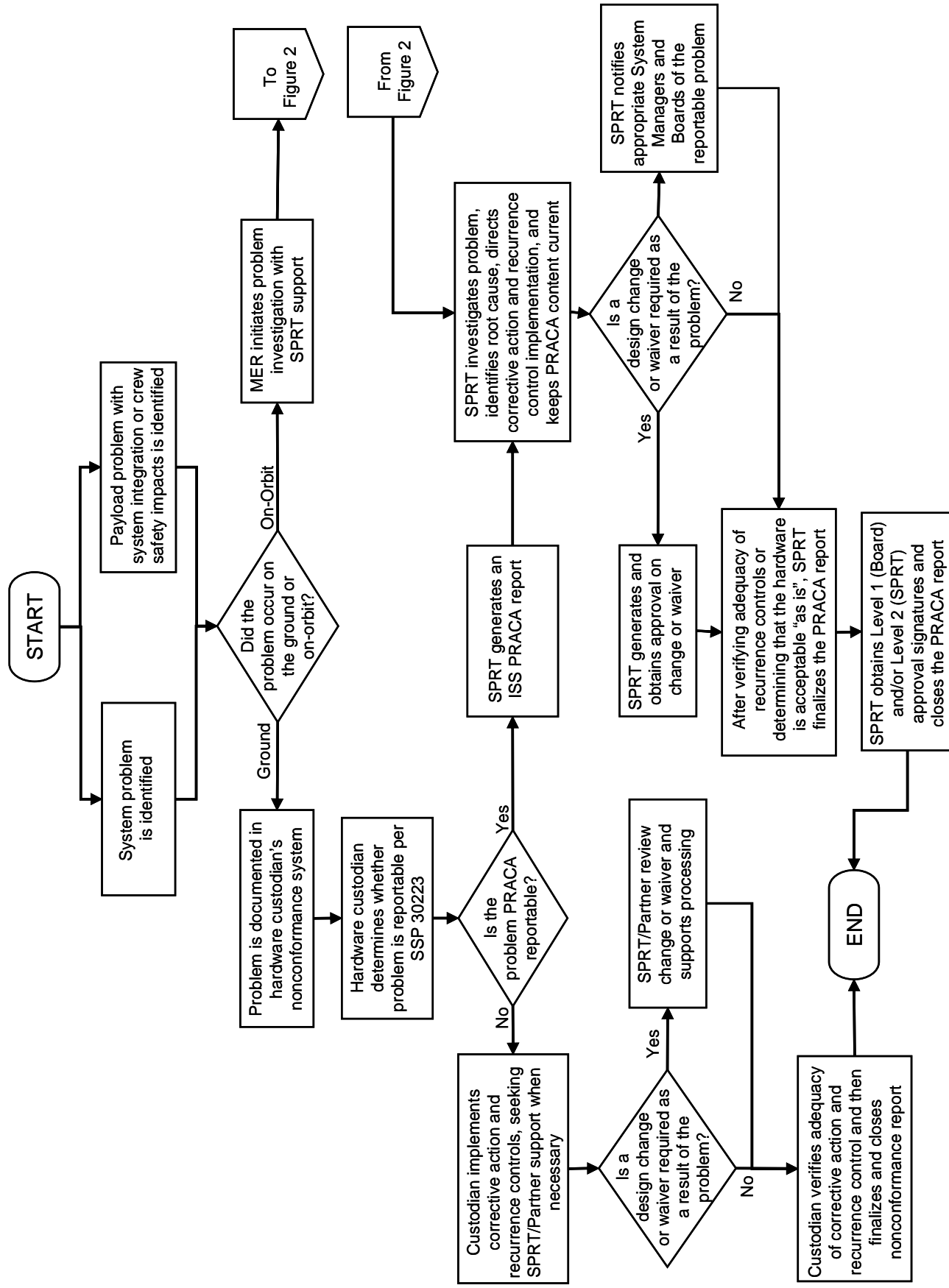
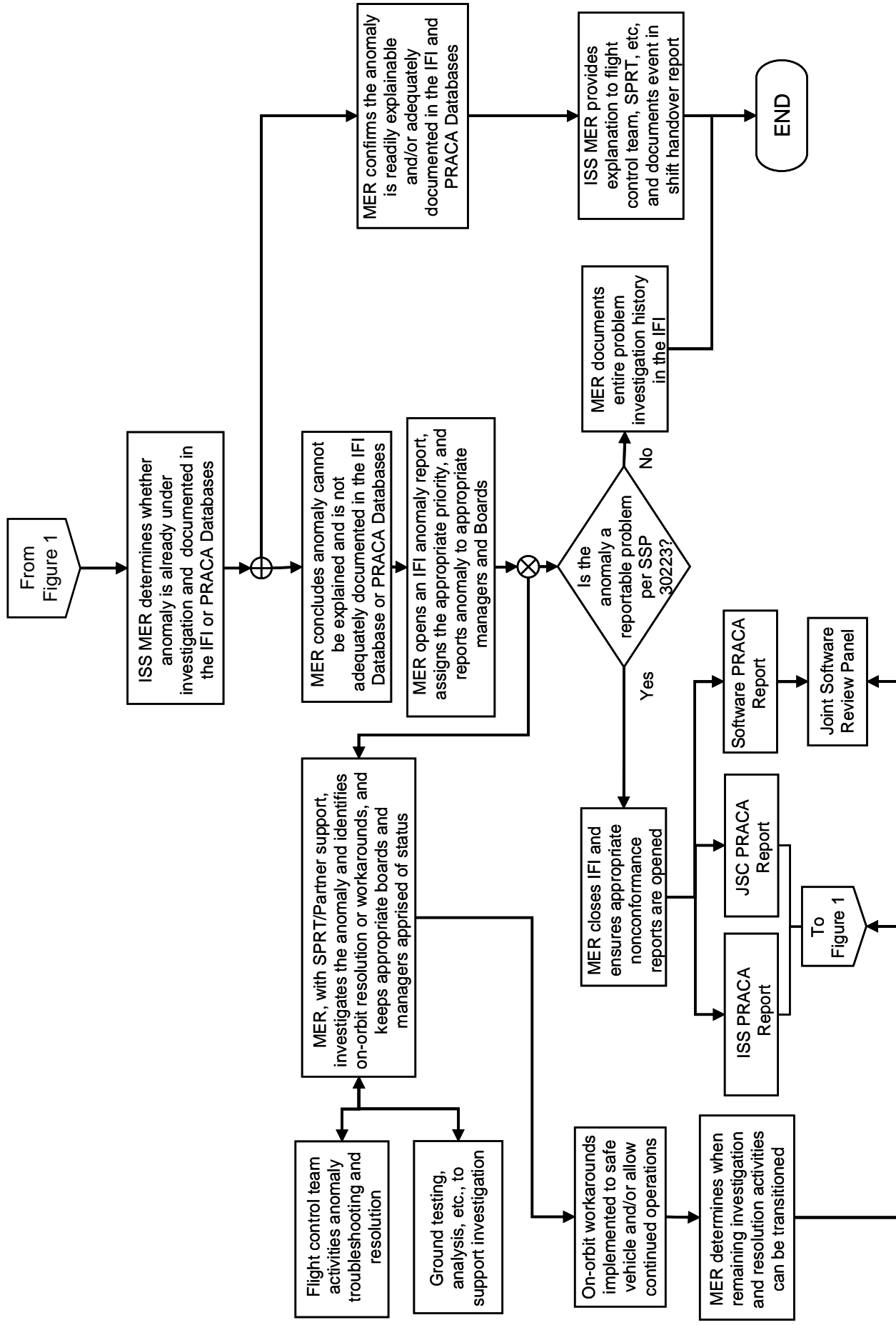


Figure ISS-5.1.1. Anomaly Resolution Process (Part 1)



**Figure ISS-5.2. Anomaly Resolution Process (Part 2)**

- S3. Information related to active on-orbit anomaly investigation activities is readily available and accessible via the ISS MER Web site.

For example, information regarding anomaly resolution team meeting information, minutes, and supporting analysis can be obtained from file folders available from the ISS MER Web site. In addition, hyperlinks are provided that allow quick and direct access to anomaly reports documented within the ISS MER's IFI database and other applicable ISS PRACA databases.

- S4. Criteria are clearly established above and beyond the authority granted to the ISS Flight Director during real-time operations for determining what levels of management approval are required for implementing on-orbit troubleshooting and anomaly response actions.

For example, MGT-OA-019 establishes clear criteria defining when anomaly resolution activities may be approved at the ISS MER Manager and Flight Director level and when such activities must be elevated to the IMMT and governing ISS Program Boards for approval.

- S5. Criteria are clearly defined to be used by anomaly resolution teams in determining the impacts and risks associated with an on-orbit anomaly and potential response actions.

For example, MGT-OA-019 provides a detailed checklist to be used by all anomaly resolution teams to support investigation efforts, development of fault trees, comparison of risks, etc.

- S6. Overall, the established on-orbit anomaly resolution process ensures thorough, timely, and meaningful response to all on-orbit anomalies and assurance that appropriate steps are taken to understand, document, communicate, and mitigate real-time and near-real-time risks.

- S7. The SPRTs do a fairly good job of resolving specific anomalies and in updating operations procedures when required to support the anomaly resolution.

### Deficiencies

The seven anomaly resolution process deficiencies identified by the continuous process improvement team are as follows:

- D1. Many of the existing requirements documents, bilateral/multilateral agreements, and work instructions governing the anomaly resolution process are outdated, inadequate, and in need of revision. In addition, there are numerous inconsistencies and conflicts within and between existing ISS requirements documents, agreements, and work instructions associated with the anomaly resolution process and other ISS processes.

- D2. There is a lack of meaningful metrics, consistent Program management oversight, and adequate quality assurance participation to monitor overall ISS MER and SPRT performance and the effectiveness of the anomaly resolution process.

- D3. Trending of ISS system performance and recurring anomalies is inconsistent and non-standardized, with inadequate definition of trending requirements, guidelines, and expectations.

- D4. Several of the existing anomaly reporting databases and other tools (e.g., Web sites) that support the anomaly resolution process are not adequate to efficiently support current ISS Program needs and long-term sustaining of the ISS.

- D5. Training for individuals who participate in and oversee the anomaly resolution process has been infrequent, is often inconsistent with requirements and processes, and is at such a high level that it has not meaningfully contributed to overall process improvement or compliance.

- D6. Several organizations are not implementing current portions of the anomaly resolution process requirements and/or work instructions, mostly due to conflicting or outdated requirements.

- D7. The quality of the historic anomaly reports stored within the various ISS anomaly reporting databases is inconsistent and often poor, due in significant part to the fact that the ISS Program lacks adequately qualified and trained quality assurance personnel to support and oversee the anomaly resolution process.

## Corrective Actions / Process Improvements

The continuous process improvement team established for the anomaly resolution process recommended several corrective actions to ISS Program management between February and November 2003 to resolve the deficiencies summarized above. In addition, a detailed schedule for implementing those actions has been developed and is being maintained by the team under the purview of the ISS Vehicle Office and SWG chairperson. Although numerous tasks are being tracked on the schedule, those actions generally fall into one of the following seven corrective actions:

- A1. Update existing requirements documents, bilateral/multilateral agreements, and work instructions, with priority being given to requirements and documents governing hardware that is already on orbit. *{Addresses Deficiencies 1 and 6}*
- A2. Identify, establish, and implement meaningful anomaly resolution process metrics, as well as a Quarterly Management Review (QMR) where ISS Program Management evaluates open anomalies, assesses how well teams are managing/mitigating risks, evaluates aggregate risk associated with multiple anomalies, assesses/resolves process issues, etc. (i.e., a “top-down” individual and aggregate system review). *{Addresses Deficiencies 2 and 3}*
- A3. Clarify and, where appropriate, expand trending requirements and establish a formal process for trending ISS system performance and anomaly history. *{Addresses Deficiency 3}*
- A4. Overhaul the ISS anomaly reporting databases and associated tools to support long-term sustaining of the ISS. Coordinate with the Shuttle Program, Johnson Space Center (JSC), and other NASA and commercial organizations to identify lessons learned, available systems and tools, and areas of improvement. *{Addresses Deficiency 4}*
- A5. Establish an internal audit/oversight process for the ISS anomaly resolution process. *{Intended to prevent recurrence of Deficiencies 1 through 7}*
- A6. Expedite negotiations with the International Partners, on both a one-on-one basis and in multilateral forums, to establish and document an overall ISS anomaly resolution process that

governs all aspects of ISS anomaly resolution activities. *{Addresses Deficiencies 1 through 4}*

- A7. Update, and where necessary, generate new generic and specific discipline training for all personnel involved in the anomaly resolution processes, pursue the option of establishing a Web-based mandatory retraining program, and determine the need for a formalized anomaly resolution process training and certification program. *{Addresses Deficiency 5}*
- A8. Have the ISS anomaly resolution process team conduct a detailed, independent assessment of the software anomaly resolution process, including ongoing improvements, to determine the effectiveness of requirements and their implementation.
- A9. Given that the Space Shuttle Program and JSC are also considering significant anomaly resolution process improvements independent of each other and the ISS Program, develop rationale to form a JSC- and/or Agency-level team to determine the feasibility of combining the improvement efforts and key portions of these processes.
- A10. Perform a quality review of currently closed and open records within the ISS IFI and PRACA databases to determine whether any of those records were closed without resulting in a waiver being generated when restoration of full functionality and compliance was not accomplished. Where waivers should have been generated, provide the anomaly record information to the team established to review all open waivers, deviations, and exceptions as part of ISS Continuous Improvement Action ISS-1. *{Addresses Deficiency 7}*

To help ensure that ISS Program management was fully aware of the quality issues identified by the anomaly resolution process continuous improvement team and documented within Deficiency 7, members of the team from the ISS Vehicle and S&MA offices generated a “white paper,” JSC-49939, *Proposed Plan to Address Deficiencies Regarding the Management and Implementation of Quality Assurance Requirements and Processes Pertaining to the ISS Problem Reporting and Corrective Action (PRACA) Process*, which was released on September 16, 2003. A new ISS Continuous Improvement Action, ISS-12, was opened to address the quality issues raised by the Deficiency 7 and further expanded upon JSC-49939.

## STATUS

### Action 1

For Action 1, which addresses existing requirements and process documentation, significant progress has been and continues to be made in updating existing requirements documents, bilateral/multilateral agreements, and work instructions, including:

- Released a significant revision and expansion of SSP 30223 for review within NASA and by NASA's International Partners. The revised document incorporates lessons learned from over four years of on-orbit operations and additional detail regarding integrated roles and responsibilities within NASA and between NASA and its Partners.
- Released an interim update of MGT-OA-019 to incorporate lessons learned from the *Columbia* Accident Investigation Board findings regarding the reporting and dissemination of anomaly information to the IMMT. The updates are being used during real-time operations as well as during Mission Control Center (MCC) simulations involving joint ISS/Shuttle operations to ensure their effectiveness.
- Modified requirements within SSP 41170, Configuration Management Requirements, to formally authorize use of a minor versus a major waiver process and to define clear lines of responsibility regarding who must review and approve such waivers.
- Modified nonconformance requirements defined in SSP 41173, Space Station Quality Assurance Requirements, to incorporate the major and minor waiver business practices currently being used by the ISS Program and to bring the high-level nonconformance processing requirements more in line with MIL-STD-1520C, Corrective Action and Disposition System for Nonconforming Material (i.e., Department of Defense nonconformance process requirements).
- Released a draft of the MCC Operations Integration Procedures (OIP) document for NASA and Partner review. The OIP integrates and expands upon various aspects of MCC operations previously defined in separate documents. The OIP includes processes for real-time communication of anomaly information between the various NASA and Partner engineering, operations, and support teams, as well as the transition

of real-time to near-real-time anomaly resolution activities.

### Action 2

Action 2 addresses the need to establish process metrics and a "top-down" individual and aggregate system review. Process metrics that measure how effective the SPRTs and ISS MER are in performing their anomaly resolution activities and complying with ISS Program requirements and processes have been drafted and are being reviewed against the new revisions to SSP 30223, SSP 41173, SSP 41170, and MGT-OA-019. Finalization and implementation of these metrics is not expected until early 2004 after the SSP 30223 requirements are finalized.

Since the ISS Program has several management forums that currently evaluate certain ISS risks and various aspects of system manager performance, the option of modifying one or more of these forums to provide the desired "top-down" individual and aggregate system review and process effectiveness rather than creating a new and additional QMR is being investigated.

### Action 3

Action 3, which involves clarification and expansion of trending requirements, is being addressed separately under ISS Continuous Improvement Action ISS-6.

### Action 4

Activities associated with Action 4, which involves the update of ISS anomaly reporting databases and associated tools, are still ongoing. The ISS S&MA Office, with participation from the anomaly resolution process continuous improvement team, is drafting requirements for an integrated ISS anomaly reporting system that can be used to govern the upgrade or replacement of the existing ISS IFI and PRACA Data System (PDS) databases. As part of this effort, S&MA is coordinating with the Shuttle Program and JSC, both of which are going through similar tool and process upgrade efforts, to identify potential areas of standardizing the tools and processes, as well areas where integrating the tools and processes between Programs might be warranted.

In addition to the anomaly resolution database upgrade efforts, significant progress has been made in improving and adding to the tools used to disseminate anomaly-related information.

First, the SPRT Web site has been restructured to enable SPRTs to manage and update their own sections of the Web site. This has resulted in more timely and consistent dissemination of SPRT meeting information, minutes, actions, etc. It has also resulted in higher confidence that the information presented on the Web site is current and up to date.

Second, the flight control team has created and implemented an MCC Anomaly Tool to augment the existing IFI and PDS databases. The MCC Anomaly Tool is intended to document all on-orbit anomalies as soon as they occur. When the ISS MER is notified of the anomaly and generates the appropriate IFI, the MCC Anomaly Tool is updated to reference the IFI and is then closed. This has significantly reduced the likelihood that the MER is not informed about an anomaly that occurs during off-nominal ISS MER working hours that wasn't severe enough to warrant calling in the ISS MER Manager to support real-time response activities.

In addition, the MCC Anomaly Tool is being used to track the investigation and disposition of those anomalies that are related to operations and that do not directly involve and/or affect ISS hardware or software, such as operator errors.

Third, the POIC's Payload Anomaly Report (PAR) system has been modified to require a documented assessment of each payload anomaly for potential impacts on ISS systems and crew safety and health to be performed and documented. The PAR process has also been clarified to require that any payload anomalies with potential ISS system or crew health and safety impacts be investigated and resolved under ISS MER processes. ISS MER Managers and MER S&MA personnel have also obtained access to the PAR system and perform separate reviews of payload anomalies to ensure that those anomalies do not pose any potential integration impacts with ISS systems or crew health and safety.

In addition, the POIC and ISS MER now conduct daily teleconferences where system and payload anomalies as well as upcoming plans are discussed to ensure that existing anomalies will not adversely affect system and payload activities being planned.

#### **Action 5**

Action 5, which deals with the establishment and implementation of an internal audit/oversight process for the ISS anomaly resolution process, is being addressed separately under ISS Continuous Improvement Action ISS-12.

#### **Action 6**

As part of Action 6, which addresses the need to expedite negotiations with the Partners to better integrate them into an overall ISS anomaly resolution process, several efforts are under way.

First, NASA has initiated and is continuing in-depth process discussions with the Canadian Space Agency (CSA) and the European Space Agency (ESA). These discussions are focusing on current processes, how to improve integration of CSA and ESA into those processes, and where to modify those processes to support improved integration. Discussions have also been initiated with the Japanese Aerospace Exploration Agency and Rosaviakosmos, the Russian Aviation and Space Agency, and in-depth process discussions are planned for early 2004. Feedback from these discussions and any agreements reached are being flowed back into the various requirements, bilateral/multilateral agreement, and work instruction updates being pursued as part of Action 1.

Second, the ISS MER is working with the flight control team and various Partners to better determine how to improve integration of the Partners within the various process tools (e.g., Chits, IFI Database, PRACA databases). As improvements are identified, activities to test those improvements are being implemented. For example, efforts are currently under way to incorporate ESA into the ISS Chit process for current real-time operations. Once those efforts are complete, Chit simulations among the ISS MER, ESA, and the flight control team will be conducted to verify the effectiveness of those changes.

#### **Action 7**

Efforts to implement Action 7, which addresses training and certification of personnel involved in the anomaly resolution process, have begun. Personnel who work in and support the MCC are currently going through flight simulations to train them to the process changes that have been made. However, development of detailed anomaly resolution training beyond that already incorporated into existing flight controller and ISS MER certification programs is still ongoing and is not expected to be ready for implementation until early to mid-2004.

#### **Action 8**

Given that efforts are under way to establish an internal audit/assessment process for the ISS anomaly resolution process under ISS Continuous Improvement Action ISS-12, it was decided that assessment of the software anomaly resolution process should be

performed under the purview of the new audit/assessment process. Therefore, refer to ISS Continuous Improvement Action ISS-12 for further discussion regarding the establishment of the audit/assessment function.

#### Action 9

Briefing materials describing the pros and cons of combining all or certain portions of the ISS, Space Shuttle Program, and JSC anomaly resolution processes were developed and provided to ISS Program management in mid-October 2003 and are under evaluation.

#### Action 10

The review of records within the ISS IFI and PRACA databases to determine whether waivers were appropriately generated when restoration of functionality and compliance was not achieved is being performed under the purview of the ISS S&MA/PR Office in its support to resolve the ISS Continuous Improvement Action ISS-1 and will be reported at a later date.

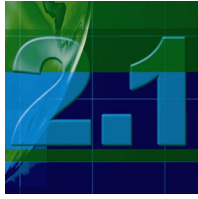
#### FORWARD WORK

Continue efforts to implement the recommendations from the process improvement team and to monitor the effectiveness of the implemented corrective actions.

#### SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Oct 03 (Complete)	Develop corrective action/improvement schedule
ISS Program	Nov 03 (Complete)	Update ISS Quality Assurance requirements
ISS Program	Dec 03 (Complete)	Upgrade SPRT Web site

Responsibility	Due Date	Activity/Deliverable
ISS Program	Dec 03 (Complete)	Implement MCC Anomaly Tracking Tool
ISS Program	Jan 04 (Complete)	Update ISS Configuration Management requirements
ISS Program	Feb 04	Interim update of On-Orbit Anomaly Process Work Instruction, MGT-OA-019
ISS Program	Mar 04	Update ISS PRACA requirements document
ISS Program	Mar 04	Complete evaluation of update/ replacement options for ISS PRACA and IFI databases
ISS Program	Apr 04	Complete MER/MER Manager and generic IFI/PRACA/SPRT training for NASA
ISS Program	May 04	Update JSC government-furnished equipment PRACA requirements document
ISS Program	Jul 04	Replace MGT-OA-019 with multilateral agreement that covers entire ISS Program anomaly resolution process
ISS Program	Dec 04	Complete update/ replacement of ISS IFI and PRACA databases
ISS Program	Dec 04	Complete update of NASA/Partner bilateral/multilateral agreements associated with anomaly resolution



# ISS Continuous Improvement Actions

## *ISS Continuous Improvement Action 6*

Review ISS system performance trending requirements and implementation status and make recommendations for improvement.

### BACKGROUND

Trending of International Space Station (ISS) system performance and recurring anomalies is essential in assuring the successful assessment and management of risk to support the long-term operation and sustainment of the ISS. The importance of adequate trending increases as ISS systems and operations become more complex through assembly activities and as ISS systems age. The grounding of the Shuttle fleet and the resulting impacts upon ISS systems with preventive maintenance and calibration requirements, as well as impacts to the resupply capability, have reemphasized the importance of trending.

The ISS Program is reassessing the ISS system trending processes. The goal is to identify potential weaknesses and areas of improvement in the Program's ability to detect and respond to adverse trends or recurring events before they lead to an eventual failure that significantly impacts crew safety or mission objectives or that lead to a catastrophic failure. Improvements in trending should also lead to better decision-making regarding logistics, spares provisioning, reliability predictions, and resource management.

### ISS PROGRAM IMPLEMENTATION

The ISS Program has divided its efforts to assess and improve the overall trending process into three key areas, each discussed separately below:

1. System performance trending
2. Anomaly recurrence trending
3. Process trending

#### **System Performance Trending**

System performance trending is needed to indicate how well ISS systems are performing over time and to provide insight into any adverse or unexpected trends that, while not yet a problem, could result in system failures or additional anomalies if preventive actions are not taken.

An evaluation of system performance trending within the ISS Program confirmed that detailed trending requirements and expectations have not been clearly defined and documented. As a result, the trending that is performed varies significantly from system team to system team, contractor to contractor, etc. In addition, the level of trending that is performed also varies significantly across systems, from little trending for some systems to an extensive amount of trending for other systems. Where teams are performing trending assessments for their particular systems, the results of such assessments are not always effectively communicated outside of the team.

The ISS Program has initiated several efforts to establish a more consistent and meaningful system performance trending process.

First, the Statement of Work within the ISS Vehicle Sustaining Contract has been modified to clarify that system performance trending is a requirement of the ISS Vehicle Sustaining Contractor.

Second, the ISS Vehicle Office and Vehicle Integrated Performance and Resources (VIPeR) team, with support from the NASA and ISS Vehicle Sustaining Contractor Chief Engineers, have initiated efforts to assist the various system teams in establishing system-by-system trending plans. It is intended that the trending plan developed for each system would define what parameters and performance characteristics need to be trended, how those performance trends will be analyzed and used by the system manager, how those trends will be evaluated across multiple systems, and how and when those trending analysis results will be disseminated throughout the ISS Program and reported to ISS Program management.

Third, an evaluation is under way as to how and whether existing databases and tools can be used to support effective and efficient trending of system performance. The objective of the evaluation is to determine where changes to the existing databases and tools are needed and whether new databases and



tools should be acquired to help improve overall trending activities.

### **Anomaly Recurrence Trending**

Trending of recurring anomalies is needed for several reasons. First, such trending is needed to identify areas where an investigation team may not have adequately identified and implemented adequate corrective actions and recurrence controls, as well as whether the root cause of the anomaly may not have been accurately identified. Second, anomaly recurrence trending needs to be performed to identify areas where the ISS Program may have previously accepted the risks associated with a rare, infrequent, or unexplained anomaly but now may need to revisit that risk acceptance decision to ensure that the decision rationale is still valid. Third, trending of anomalies plays a direct role in validating and adjusting system hardware life predictions, maintenance and calibration frequencies, reliability calculations, sparing planning, and other logistics and maintenance activities.

The ISS Problem Reporting and Corrective Action (PRACA) Data System (PDS) is the database used to document the investigation and disposition ISS hardware nonconformances that must be elevated to an ISS Program System Problem Resolution Team (SPRT) or Program board for disposition approval. Hardware nonconformances that do not require elevation to an ISS SPRT or Program board are tracked within the hardware provider's nonconformance system.

The PDS incorporates several features that allow a user to trend recurring nonconformances. These features are currently being used by the ISS Reliability and Maintainability organization in support of the system managers and their SPRTs to determine whether certain hardware items are exhibiting problems that warrant a change in the predicted life of the hardware, which in turn could lead to potential changes in logistics and sparing planning, as well as potential changes in system design and operation.

In addition, the search and query functions built into the ISS PDS allow the system managers and their SPRTs established for the various ISS systems to determine whether a newly reported nonconformance has previously occurred and, if it has, how often it has occurred, any unique factors associated with previous occurrences, etc.

The Johnson Space Center (JSC) Government Furnished Equipment (GFE) PRACA Database and ISS Program Professional Version Control System

are the primary databases used by the ISS Program to document the investigation and disposition of ISS software nonconformances, including those Software Program Notes that are written to address software anomalies that might recur because the Program has elected to defer or waive implementation of resolution activities.

To help ensure that SPRTs are doing an adequate job of trending recurring anomalies and that they are equipped with the proper tools to perform such trending, the ISS Program has initiated the following process improvement actions, with investigation and discussion still ongoing as to whether any additional improvement actions are required.

First, NASA and its ISS Vehicle Sustaining Contractor, Boeing, have initiated periodic systematic reviews of "recurring events" being experienced at the integrated stage, element, system, subsystem, hardware, software, and component levels. The objective of these reviews is to ensure that the ISS Program has adequately identified the root cause of those events and that any corrective actions and recurrence controls implemented are still sufficient. In addition, the reviews are intended to identify any differences in the anomalies, ISS configuration, or other factors that would warrant the need to modify previous decisions to accept the risks associated with those anomalies and the previously implemented corrective actions and recurrence controls.

Second, NASA has initiated efforts to update the existing ISS anomaly and nonconformance reporting databases as part of ongoing anomaly resolution process improvement efforts. As part of these upgrade efforts, consideration is being given to how anomalies and nonconformances are categorized so that the tools can be configured to improve automated trending of recurring anomalies. Additional information regarding ISS Program efforts to upgrade the various ISS anomaly resolution tools, including schedules for such upgrades to be complete, is provided under ISS Continuous Improvement Action ISS-5.

### **Process Trending**

Process trending is intended to uncover inefficient and ineffective areas within the various ISS processes (e.g., anomaly resolution process, waiver process), as well as to identify where organizations and personnel may not be fully compliant with or knowledgeable in the process requirements.

In the area of anomaly resolution, the ISS Program has identified the need to establish metrics that can be

used to measure how effectively the various anomaly resolution teams [e.g., ISS Mission Evaluation Room (MER), SPRTs] are implementing and complying with the ISS anomaly resolution process. The establishment of such metrics and how they will be trended is addressed separately as part of the overall anomaly resolution process improvement effort in ISS Continuous Improvement Action ISS-5.

To determine the effectiveness of other ISS Program processes and how well the various ISS Program organizations are complying with those processes, as well as any adverse trends in those processes, consideration is being given to the establishment of an internal audit/surveillance function that resides within the ISS Safety and Mission Assurance (S&MA) organization independent from the engineering and configuration disciplines. Additional information regarding ISS Program consideration of an internal audit/surveillance function is provided separately under ISS Continuous Improvement Action ISS-12.

## **STATUS**

### **System Performance Trending**

The Statement of Work has been modified to clarify that system performance trending is a requirement of the ISS Vehicle Sustaining Contractor. Although it was determined that each system manager was performing system trending to some extent, the change to the contract has been communicated to NASA and the ISS Vehicle Sustaining Contractor system manager to ensure they understand their role and responsibility for system trending activities.

The ISS Vehicle Office and Boeing VIPeR team have obtained detailed reports from a majority of the system teams that describe the various parameters being evaluated and trended by those teams, where those teams report their trending information, and how those teams use the trending data to support decision making activities. Feedback from all subsystem teams is expected by the end of January 2004.

With the information received to date from each subsystem team, the VIPeR team has initiated efforts to formalize the trending process to improve consistency between how the various teams are performing, documenting, and disseminating their trending information. Plans are to issue an ISS work instruction or other appropriate document by May 2004 to standardize system performance trending and better define the performance trending process.

Evaluation of the various databases and tools used to support effective and efficient trending of system

performance is under way. A Task Order has been drafted to authorize the ISS Program Integration contractor to evaluate options for upgrading/replacing the ISS PDS to not only improve anomaly reporting and documentation activities, as discussed further as part of ISS Continuous Action ISS-5, but also to determine what changes should be made to improve anomaly and process trending. The ISS MER Item for Investigation Database used to initially document on-orbit anomalies, the JSC GFE PRACA Database, and several other databases are also within the scope of the review that will be performed under the Task Order.

## **FORWARD WORK**

The ISS Program will continue efforts to implement the recommended improvements discussed above for improving trending of system performance, recurring anomalies, and process effectiveness and compliance.

The ISS Vehicle Office and VIPeR plan on completing initial reviews with all of the system managers and SPRTs by March 2004 to determine what system trending is currently being performed and how that information is being recorded, disseminated, and used by the system managers, ISS MER, SPRTs, and other organizations to support decision-making. Based on these reviews, an improvement plan and associated implementation schedule will be developed and submitted to ISS Program management for review and concurrence.

Periodic systematic reviews of "recurring events" will continue for each system, with the frequency of each system review being based on the number of anomalies associated with the system, the number of recurring anomalies, schedules for implementing corrective actions and recurrence controls, and other appropriate factors.

Updating the various ISS anomaly resolution process databases and tools will continue as part of ISS Continuous Improvement Action ISS-5. A review of the other ISS Program databases and tools that are available and/or being used by the ISS Program to determine whether changes to those databases and tools are required is expected to be complete by the end of March 2004.

Based on the above reviews, any additional training requirements required for ISS MER personnel, system managers and their technical teams, S&MA personnel, and other appropriate organizations will be identified and implemented.

Internal audits and surveillance function within the ISS Program is provided separately as part of ISS Continuous Improvement Action ISS-12.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Ongoing	Perform periodic system reviews of "Recurring Events"
ISS Program	Dec 03 (Complete)	Vehicle Sustaining Contract change

Responsibility	Due Date	Activity/Deliverable
ISS Program	Jan 04 (Pending)	Issue Task Order for Program Integration Contract to review tools and databases
ISS Program	Mar 04	Complete current trending process evaluations
ISS Program	Mar 04	Complete review of ISS Program trending tools/databases
ISS Program	May 04	Issue formal Work Instruction documenting system performance trending process and requirements
ISS Program	May 04	Identify/implement additional trending tool training



# ISS Continuous Improvement Actions

## *ISS Continuous Improvement Action 7*

The ISS Program will assess its hardware (ground and on-orbit) to verify that they are within the hardware qualification and certification limits, in light of the grounding of the Space Shuttle fleet. Where life limits are approaching, take appropriate action.

### BACKGROUND

Flight hardware is designed to a set of specifications that identifies the lifetime of that hardware, any maintenance, and the verification to validate the condition of the hardware that will provide assurance of the ability to achieve this lifetime. The International Space Station (ISS) is composed of three general lifetime categories of hardware. These categories are (1) hardware designed to remain on orbit without maintenance for the life of the Station, (2) hardware designed for periodic replacement and/or maintenance, and (3) flight hardware on the ground that must be launched within a specified time period or be recertified.

### ISS PROGRAM IMPLEMENTATION

With the grounding of the Space Shuttle fleet, the ISS Program has systematically reviewed hardware certification limits and taken the necessary actions. With the exception of the limited-life certification hardware, the ISS has significant margin remaining in its certified design life. As the certified design lifetime is approached, recertification will be examined if use of the Station is intended to extend beyond its original certification period.

A limited set of hardware on orbit is designed for periodic replacement and, therefore, carries certification limits that affect its useful life. Within weeks of the *Columbia* tragedy, all on-orbit hardware with certification limits was reviewed. Where additional testing or analyses could be done to extend these certification limits, this testing and analysis was approved and performed. Where this was not possible, strategies and justification were developed to allow continued use of these items in an acceptable manner.

Some ISS hardware now awaiting launch at Kennedy Space Center has a limited storage life, such as the electrical power system batteries and solar array wings. Systematic reviews were completed by each

ISS subsystem to determine needs for on-ground preventative maintenance, battery boost charging, reconditioning of batteries, extension of limited storage life requirements, and additional checkouts due to launch delays. The reviews involved an item-by-item and flight-by-flight reevaluation of ISS hardware relative to these areas and identified recommendations for new requirements, storage life extensions, and confidence checks. The Space Station Program Control Board has approved actions to meet these new requirements. The ISS Program has established on-ground preventative maintenance requirements for spare hardware still on the ground and not integrated into larger elements. However, no on-ground preventative maintenance requirements exist for hardware once integrated into larger elements, such as truss sections. Launch delays due to *Columbia* have driven the ISS Program to assess and define the preventative maintenance requirements for integrated hardware waiting for launch. The ISS Program is taking action to define and meet these requirements to gain the confidence that integrated hardware will function as required when assembled on the ISS.

### STATUS

The ISS Program reviewed all systems and expanded on the original preventative maintenance requirements to also address recommendations for confidence tests due to launch delays. For hardware integrated into carriers, the ISS Program de-integrated the hardware, is performing the maintenance per nominal logistics processes, and has established reintegration milestones to occur once launch dates are identified. Based on these assessments, a new set of preflight confidence tests has been added to the Program.

The ISS Program assessed the impacts to electrical power system batteries for various storage options, and is implementing procedures to minimize degradation. The planned approach is to conduct boost-charging monthly and ambient reconditioning every six months. The ISS Program is assessing additional

cold reconditioning and orbital rate capacitance testing based on results obtained over time.

To mitigate risks associated with long-term stowage of solar array blankets in their launch configuration, the right and left solar array blanket boxes of flight wing number 5 were de-integrated from the launch configuration, and data were collected on panel stiction during solar array blanket deployment. Based on the test results and analysis, the ISS Program extended the acceptable storage limit to 63 months. Options are currently being pursued for extending storage limit to 82 months. This may involve unlatching solar array blanket boxes in place on the integrated elements to relieve compression on foam components in the stowed configuration.

### FORWARD WORK

All ground and on-orbit activities associated with lifetime certification issues due to launch delays are ongoing and will continue until new launch dates are established. Current plans for maintenance due to truss launch delays are summarized in Table 7.1.

### SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Mar 03 (Complete)	Review certification limits of on-orbit hardware
ISS Program	Jun 03 (Complete)	Define/Review certification limits of flight hardware on the ground
ISS Program	Jun 03 (Complete)	Wing 5 Solar Array Deployment Test
ISS Program	Ongoing	Battery Testing and Conditioning
ISS Program Office	Ongoing	Perform preventive maintenance to ensure ISS hardware awaiting launch will function properly on orbit

**Table 7.1 Current Plans for Maintenance Due to Truss Launch Delays**

Truss Delays Item	Plan	ECD	Flight Effectivity						
			LF-1	ULF1.1	12A	12A.1	13A	13A.1	15A
Utility Transfer Assembly Spare	Deintegrate and conduct annual cycling preventative maintenance (complete 10/7/03)	Complete	X						
Trundle Bearing Assembly Spare	Deintegrate and conduct annual cycling preventative maintenance (complete 10/6/03)	Complete	X						
Flex Hose Rotary Coupler Spare	Deintegrate and conduct annual cycling preventative maintenance (complete 10/7/03)	Complete	X						
External Television Camera Group	Communication and Tracking Subsystem to determine need for periodic preventative maintenance and bring recommendation to Program	2/04	X						
Control Moment Gyro	Deintegrate and conduct preventative maintenance (spin up every 2 years and gimbal rotation annually)	5/04	X						
Lightweight Multipurpose Carrier	Deintegrate and conduct inspections and bolt replacements	4-May	X						
Corrosion Inspections	Perform monthly inspections on all hardware - disposition, document, clean and protect where required.	Monthly	X	X	X	X	X	X	X
Pump Module Spare	Perform functional checkout within two years of launch (last completed 9/03)	9/03		X					
Solar Array Wing	Perform tests and analyses on Flight Wing 5 to extend storage life to 63 months (completed 11/03). Complete analysis of foam compression and identify actions needed to extend storage life to 82 months.	2/04			X		X		X
Ammonia Mass Check	Conduct preflight confidence test (PFCT) to check ammonia mass	L-120d			X		X		X
Pump Flow Control Subassembly Valve	Conduct PFCT to verify flow control valve functionality before flight	L-120d			X		X		X
Pump Operation	Conduct PFCT to verify pump functionality before flight	L-120d			X		X		X
Photovoltaic Active Thermal Control System Sensors Check	Conduct PFCT to verify sensors before flight	L-120d			X		X		X
Drive Latch Assemblies	Conduct preventative maintenance in place on Solar alpha rotary joint – disengage bull gear and cycle manually	3/04			X		X		
Battery Boost Charging	Conduct battery boost charging monthly	Monthly			X		X		X
Battery Reconditioning	Conduct battery reconditioning every six months	Every 6 months			X		X		X
Electric Power System ORUs Electrically Erasable Programmable Read Only Memory	Perform annual Electrically Erasable Programmable Read Only Memory pre-fresh on electric power system ORUs concurrent with a battery reconditioning event	Annual			X		X		X
Battery Orbital Rate Capacitance Test	Process change request to conduct annual tests – will require active cooling using ammonia test support equipment	Annual			X		X		X



# ISS Continuous Improvement Actions

## *ISS Continuous Improvement Action 8*

Review lessons learned from ISS operations and identify any enhancements to ISS hardware or software that significantly mitigate risk to crew safety and mission success. Survey ISS system teams to identify any further modifications to hardware or software that reduce risk.

### BACKGROUND

Enhancements to the International Space Station (ISS) design go beyond the minimums required to meet ISS Program requirements and significantly mitigate risk to crew safety or mission success. To identify improvement candidates, the ISS Program conducted a bottom-up review and has selected several proposals for implementation. The total list of suggested improvements will serve as an input to the ISS Pre-planned Product Improvements (P<sup>3</sup>I) process.

### ISS PROGRAM IMPLEMENTATION

This review was conducted in two phases. The first phase consisted of an independent review by ISS operations, engineering, and safety personnel of system design deficiencies and operational techniques that represent significant risk to the crew or to the vehicle. Potential hardware or software modifications that would mitigate the risk were identified. These potential modifications, called ISS enhancements, were intended to reduce risks to crew safety and mission success. Flight controllers from the Mission Operations Directorate and engineers in the Mission Evaluation Room in the Mission Control Center reviewed on-orbit system performance, known software deficiencies, and lessons learned from on-orbit operations to identify ISS enhancements. Safety engineers reviewed hazard reports and nonconformance reports to identify ISS enhancements. Inputs from each organization were compiled, and the results were reviewed and grouped in three categories. These categories are enhancements that:

1. Should be assessed by the Program immediately due to the potential for significant risk reduction.
2. Are covered by ongoing work.
3. Have potential benefits but do not merit immediate Program action.

Enhancements recommended for immediate Program review were presented to the Space Station Program Control Board (SSPCB). These included enhancements

to External Active Thermal Control System redundancy and enhancements to the oxygen system on board the ISS. The SSPCB directed further study of the technical solution and estimated cost of each recommended enhancement. Enhancements covered by ongoing work were left to work through normal processes.

Phase 2 of the ISS enhancements entailed soliciting recommendations from each system team to review risks and bring forward suggested ISS enhancements to mitigate these risks. These included additional infrared sensing equipment for internal and external use on board the ISS, and External Active Thermal Control System redundancy and enhancements to the oxygen system on board the ISS. The SSPCB directed further study of the technical solution and estimated cost of each recommended enhancement.

### STATUS

Several ISS enhancements have been approved for implementation, and detailed design and development work has begun.

Examples of proposed enhancements are:

1. Electrical power jumpers to increase robustness in the case of certain failures.
2. Software modifications to facilitate recovery from a lockup of the thermal rotary joint.
3. Oxygen system outlet hose that includes a check valve to reduce the risk that contamination could cause a problem with the ISS oxygen system.
4. Detailed design of infrared cameras for internal and external use on the ISS.

### FORWARD WORK

The ISS Program will ensure that the P<sup>3</sup>I process captures suggested enhancements, and is continually reviewing suggested enhancements to reduce the risks associated with operating the ISS.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Ongoing	P <sup>3</sup> I Recommendations to SSPCB
ISS Program	Ongoing	Implementation of approved enhancements





# ISS Continuous Improvement Actions

## ISS Continuous Improvement Action 9

Review program, project, and supporting organization contingency action plans and update them based on *Columbia* mishap lessons learned.

### BACKGROUND

The International Space Station (ISS) Program Contingency Action Plan documents the actions to be taken in the event an ISS contingency is declared. It defines the ISS Program's responsibilities in the areas of mishap reporting and the investigation process. The ISS Program has reviewed and updated its ISS Program Contingency Action Plan and the implementation plans that will be used by the investigation teams in support of the Board of Investigation.

The ISS Program reviews its Contingency Action Plan several times a year and updates the document accordingly to ensure its currency.

### ISS PROGRAM IMPLEMENTATION

The ISS Program performed an extensive review of the ISS Contingency Action Plan during the March–July 2003 time frame to reflect the lessons learned from the *Columbia* mishap and to convert the original Johnson Space Center (JSC)-ISS Lead Center Plan to an ISS Program Contingency Action Plan. The revised ISS Program Contingency Action Plan defines the lines of authority within the ISS Program Office for notifying NASA Headquarters of a potential ISS contingency and the responsible ISS officials who will lead a mishap investigation pending the establishment of a formal Board of Investigation. International Space Station Program Office and ISS support offices/directorates personnel participated in the review and the update of this Plan.

During this time, investigation teams that will be supporting the ISS Technical Action Center prepared and/or reviewed their team's implementation plan. The ISS Technical Action Center will lead technical activities associated with understanding the contingency and managing all technical actions.

The ISS Contingency Action Plan and its appendices, which contain contact information for NASA senior management, ISS Program, and JSC management personnel, have been updated and posted on an ISS

server. The appendices also contain contact information for the chairpersons and alternates of the ISS Technical Action Center's investigation teams. Access to this information and the implementation plan for the ISS Technical Action Center and its investigation team are available on the Increment Management Center Management Coordination Web site.

### STATUS

As a result of this activity, the ISS Program Manager approved the updated ISS Program Contingency Action Plan in July 2003. Using this updated plan, a simulation of an off-nominal Soyuz landing was completed in October 2003.

The NASA Headquarters Contingency Action Plan for Space Flight Operations was also updated in October 2003.

### FORWARD WORK

To enhance ISS Program preparedness in case of contingency, the following areas are being addressed:

1. NASA will complete development of the lower-level work instructions for the Technical Action Center's investigation teams and continue providing assistance to the ISS supporting center and their directorates in the development of their organizational Contingency Action Plans.
2. NASA will ensure ISS International Partners are prepared to respond to an ISS contingency event.
3. NASA will continue to perform contingency simulations for both ground and on-orbit events.
4. The Mishap Investigation Team (MIT) is a small group of people from various disciplines. NASA will review MIT membership and supplemental support, and include procedures in its contingency plan for quickly supplementing MIT activities with administrative,

computer, and database support and debris management.

5. ISS will review updates to the Space Shuttle Program's Contingency Action Plan to identify any applicable improvements.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Jul 03 (Complete)	Released revised ISS Contingency Action Plan

Responsibility	Due Date	Activity/Deliverable
ISS Program	Oct 03 (Complete)	Conducted contingency simulation
ISS Program	TBD	Integrate International Partners into the ISS Contingency Action Plan



# ISS Continuous Improvement Actions

## *ISS Continuous Improvement Action 10*

The ISS Program's avionics and software management organization will continue to evolve software development and integration processes to provide high fidelity flight software suites with higher productivity. In addition, ISS software uplink and long term sustaining processes will be updated to reflect lessons learned from ongoing ISS software upgrade activities.

### BACKGROUND

The International Space Station (ISS) spacecraft is comprised of elements provided by the space agencies of many nations. Operation of these diverse elements is integrated into a single spacecraft via the on-board software suite.

The U.S. portion of the ISS is controlled by computers both inside and outside the pressurized modules using 20 different sets of software with over 2 million source lines of flight code. In aggregate the Russians, Canadians, Italians, European Space Agency, and Japanese are providing computing capability of roughly equivalent size and complexity for a total ISS on-board software suite of 4 million source lines of code. The system is architected as a three-tier federated system managed as functional control zones. Due to the size and complexity of the software suite and the incremental development strategy, it is imperative that all development be highly structured to avoid on-orbit problems. Facilities in Houston replicate the significant aspects of each ISS configuration for overall software integration prior to uplink of the required functionality for that specific configuration.

Even though the initial ISS software has been on orbit for five years providing excellent operational performance, we have instituted a continuous improvement program that will continue to provide the same high-fidelity software with even higher organizational productivity.

### ISS PROGRAM IMPLEMENTATION

#### Development Process

Software for the ISS is developed per the Mil-Standard 2167A process. The ISS uses the Software Engineering Institute (SEI), Capability Maturity Model (CMM) as the "measuring stick" to document the maturity of each developer's processes. The industry-

accepted norm for a cost-effective, repeatable software developer is a CMM rating of Level 3.

Achieving each level in the SEI CMM process involves an assessment by knowledgeable individuals of the candidate organizations' policies, procedures, and performance data.

#### Integrated testing

The Software Development and Integration Laboratory (SDIL) in Houston is used for the formal integration and certification of the flight software suite. It has a combination of flight-equivalent and actual flight hardware computers used in appropriate combinations to replicate the on-orbit spacecraft, enabling in-depth evaluation and certification of the entire software suite.

#### Sustaining Approach

A block release approach is being used to plan and produce the sustaining software necessary to operate and maintain the spacecraft. The plan will produce three blocks of needed software sets per year in the near term and taper to one per year as operational experience is gained. Once the software has completed certification, it is uplinked to replace the initial code. In addition, the management of ISS software anomalies is under review as noted by Continuous Improvement Action ISS-5.

### STATUS

#### Development Process

The ISS Prime contractor software development sites are all at or above the desired Level 3. NASA is encouraged that the Prime contractor achieved the infrastructure to support a Level 5 rating in Houston in December 2003.

To date, over 1.25 million source lines of code have been developed and flown with minimal problems.

## Sustaining

Due to the incremental assembly of the ISS, over 1 million lines of ISS code have been developed and replaced on ISS using the sustaining process. Lessons learned from these operations have been studied, and ISS software development and uplink processes have been improved as a result.

One of the primary lessons learned is that a process is needed to ensure that the best ideas for spacecraft operability enhancements receive priority for competing resources. Our approach is to use the existing Program Software Change Request system to develop a comprehensive list of proposed software product improvements in a coordinated and structured manner from all stakeholders (i.e., crew, operations, engineering, and safety). The list will be prioritized to optimize the core software system for safety, speed, robustness, usability, and maintainability. The list will then be used for a coordinated content determination for each sustaining Computer Software Configuration Item release to implement the highest-priority software product improvements. The list will be a living document, with each new proposed change being evaluated against the existing priorities for placement of its relative priority.

## Integrated Testing

The ISS is just completing Phase 1 of an enhancement project to enable the inclusion of additional flight computers and firmware controllers into the SDIL. Phase 1 expanded the laboratory floor space and control rooms, and replaced several flight-equivalent computers with flight prototypes for the ISS Systems Integration Laboratory of the SDIL. Phase 2 will continue to expand the software/hardware integration capability with additional flight computers and firmware controllers.

## FORWARD WORK

Continue to rigorously pursue contractor process improvements and laboratory enhancements.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Dec 03 (Complete)	Houston software developers attain quality process Level 5
ISS Program	Dec 03 (Complete)	Phase 1 enhancements to SDIL
ISS Program	TBD	Phase 2 enhancements to SDIL



# ISS Continuous Improvement Actions

## ISS Continuous Improvement Action 11

The International Space Station (ISS) has implemented some initiatives to facilitate the reporting of occupational and on-orbit safety concerns by its employees.

### BACKGROUND

Safety is paramount in the minds of NASA employees. Each International Space Station (ISS) Program employee contributes to safe operation of the ISS through execution of their assigned responsibilities. Each employee is trained and encouraged to communicate safety concerns to their supervisor or team members. The purpose of a safety reporting system is to allow direct, effective communication of concerns. These concerns may be with flight hardware, software, or ground operations and personnel.

To complement the formal ground and on-orbit anomaly reporting processes described under Continuous Improvement Action ISS-5, the ISS Program has implemented an approach to increase ISS Program employee awareness of established NASA safety reporting systems. The goal is to ensure that employees are encouraged to report any safety concerns, as well as to ensure that employees are aware of the NASA Safety Reporting System (NSRS) program.

### NASA AND ISS PROGRAM IMPLEMENTATION

As recommended by the Agencywide Action Team headed by the Director of the Goddard Space Flight Center, NASA has established an Ombuds Program that is empowered to listen to and act on the concerns of Agency personnel related to safety, organizational performance, and mission success. The Ombuds who have been named at each NASA center serve as a safety valve when employees feel regular channels for raising issues and concerns are not working effectively. Each Ombuds serves as an honest broker to ensure NASA becomes more accountable and results-oriented. When issues are brought to the Ombuds, they may conduct informal inquiries, and will seek to promote a mutually satisfactory resolution of the issue or concern. Each Ombuds has the ability to raise issues directly with Center Directors, and at NASA Headquarters with the Deputy Administrator. The Ombuds are empowered to perform their duties independently and in a diligent and timely manner.

They will maintain confidentiality at all times, unless the person providing information requests or approves otherwise.

The ISS Program also actively participated in the Agencywide Safety and Mission Success (SMS) Week during November 17–21, 2003. At each staff meeting and all board and panel meetings during this period, all NASA and contractor employees were encouraged to review the *Columbia* Accident Investigation Board Report and openly discuss any cultural or technical issues that should be brought to the Program's attention.

As a further improvement, the ISS Program has implemented a link from the ISS homepage for safety reporting options. This page is also linked from other ISS office homepages. The ISS homepage clearly defines the steps that should be taken if a safety concern exists. These steps include:

1. Correct the situation yourself, if possible.
2. Report the situation to your supervisor.

If an employee feels that the situation has not been or cannot be addressed adequately at this level, or if they feel that further management visibility is warranted, they should contact:

1. The ISS Safety and Mission Assurance Manager
2. The ISS Program Manager
3. The ISS Safety, Reliability, and Quality Assurance Director

If an employee has reported the concern and has seen no action, is not satisfied with the response, or fears reprisal, that employee has the option to submit an NSRS report and/or contact a NASA Ombuds.

Additionally, NASA has modified the Close-Call reporting system to accommodate anonymous reports related to the ISS.

## STATUS

An ISS safety reporting homepage has been developed and its availability communicated to ISS personnel.

The ISS-specific results of the SMS Week are currently being assessed.

The NASA Ombuds Program was announced by the NASA Administrator on January 27, 2003.

The Agency will distribute Ombuds contact information to facilitate this method of safety reporting when other avenues are not working.

## FORWARD WORK

The ISS Program will continue to make personnel aware of the methods available to report safety concerns, as well as to modify the communication methods as improvements are identified. Additionally, the

ISS Program is evaluating options for placing proper emphasis on minority dissenting opinion, such as requiring that minority dissenting opinions be captured in meeting minutes as a standard practice.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
NASA HQ	Jan 04 (Complete)	NASA Ombuds Program announced
ISS Program	TBD	Complete review of ISS results of SMS Week
ISS Program	TBD	Resolve suggested improvements to safety concern reporting methods



# ISS Continuous Improvement Actions

## *ISS Continuous Improvement Action 12*

The International Space Station (ISS) has initiated action to make recommendations for improvements in quality assurance aspects of ISS development and operations.

### BACKGROUND

The purpose of the International Space Station (ISS) Quality Assurance (QA) program is to ensure successful activation and operation of ISS systems, overall mission success, crew safety, and effective operations and sustaining engineering. To accomplish this goal, quality processes must be established with assurances that those processes are being followed from the development and delivery of flight hardware and software to the successful performance on orbit. When failures of quality-built hardware or software or failure of personnel to follow the quality processes do occur, they must be identified, analyzed and dispositioned to ensure proper corrective action and reoccurrence control is implemented.

### ISS PROGRAM IMPLEMENTATION

The ISS Program initiated several continuous improvement activities related to this action and embarked on a far-reaching improvement plan to strengthen its QA program.

The ISS Program has identified the need to strengthen the QA role in management and implementation of its anomaly resolution processes. Specific actions are now in place to accomplish this.

Philosophical and organizational changes are being evaluated that will have a positive impact for quality in all aspects of the ISS QA program.

The ISS Program has also identified areas and developed plans to address other continuous improvement actions related to problem tracking and anomaly resolution processes, system performance trending requirements, hardware processing and operations for hardware qualification and certification limits, and software process improvements.

The need for quality process improvements is the underlying requirement expressed in several other continuous improvement actions, most notably ISS-5 (problem tracking and in-flight anomalies) and ISS-6

(performance trending). With respect to ISS-5, QA will perform audit/surveillance to assure adherence to quality requirements. With respect to ISS-6, QA will audit the systems engineering anomaly resolution-trending process and verify compliance with quality objectives. The system managers remain accountable for ensuring that recurrence trending is performed.

Our goal is to strengthen ISS QA activities while embracing the following concepts:

1. A strong quality discipline within the ISS Program to accomplish nominal ISS QA and support anomaly resolution activities.
2. Adherence to requirements and process is maintained within the ISS Program by all ISS Program organizations and personnel.
3. A knowledgeable and authoritative QA organization to assist all elements of the ISS Program.

First, SSP 30223 Problem Reporting and Corrective Action (PRACA) requirements defining NASA QA roles and responsibilities will be expanded to:

1. Enforce criteria for initiating and closing problem reports
2. Ensure rigor in problem investigations
3. Enforce documentation requirements
4. Monitor the process for conformance to requirements

Second, System Problem Resolution Teams (SPRTs) will be staffed with dedicated QA representatives to fulfill new responsibilities. We will train/certify QA representatives and other SPRT members on requirements and processes and develop process and product quality metrics. We will standardize/integrate quality expectations across all program participants. QA will manage the Mission Evaluation Room In-flight Investigation (IFI) processes and database as we fully integrate the PRACA and IFI databases.

### Additional QA Improvements

We will define and implement the following new ISS QA tasks:

- Training/certification requirements for ISS-critical processes
- Process and product quality metrics
- Anomaly recurrence trending process
- Formal contractor audit and surveillance program
- ISS internal process audit program

The following are current QA tasks that will have increasing expectations/emphasis or changing scope:

- ISS commercial off-the-shelf/government furnished equipment procurement QA reviews
- On-orbit QA
- Acceptance Data Package maintenance

### STATUS

NASA has developed prioritized plans to implement the QA improvement strategy. The first priority is to staff the SPRTs with qualified QA personnel, to form and staff an audit/surveillance group, and to provide training and certification for QA personnel.

We have initiated the following tasks to strengthen the anomaly resolution functions:

- Ensure proper initiation of nonconformance reports or PRACA records
- Ensure the anomaly records are assigned to the appropriate SPRT for analysis and resolution
- Ensure on-orbit nonconforming articles are properly identified and/or tracked
- Support the SPRTs with proper documentation of dispositions
- Support the SPRTs with root cause analysis and documentation of corrective and preventive action
- Ensure all nonconformance records are reviewed for PRACA reportability in a timely manner and ensure the quality of anomaly records

- Ensure anomaly records are complete and adequately support closure

Further, we have identified the following enhancements to the audit/surveillance tasks:

- Develop an audit and surveillance plan; perform audits and surveillance
- Develop metrics and integrate Defense Contract Management Agency metrics at the Program level
- Develop and implement an ISS Corrective Action Request system

Plans are being developed to perform training and certification at three levels, commensurate with ISS Program needs.

The personnel and other resources required to implement these organizational enhancements were presented to the Deputy ISS Program Manager recently and are being further refined.

### FORWARD WORK

The ISS Safety and Mission Assurance (SMA) Office will develop Change Requests to implement the organizational responsibilities proposed in these QA improvements. The Program will also modify task support agreements, as appropriate to hire and assign matrixed personnel.

### SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS SMA	Mar 04	Update SSP 30223, PRACA, to define NASA and contractor QA responsibilities
ISS SMA	Jun 04	Staff SPRTs with contractor QA personnel
ISS SMA	Jun 04	Begin training and certification programs
ISS SMA	Aug 04	Implement process and product quality metrics





# ISS Continuous Improvement Actions

## *ISS Continuous Improvement Action 13*

The ISS Program will assess its process for tracking Top Program Risks via the existing ISS risk management tool, specifically the Integrated Risk Management Application (IRMA), and recommend improvements where necessary.

### BACKGROUND

The purpose of risk management is to identify risks early in the Program so that appropriate mitigation plans can be put into place to effectively reduce or eliminate the risk. The risk management process provides systematic methods for identifying, analyzing, planning, tracking, controlling, communicating, and documenting risks.

### ISS PROGRAM IMPLEMENTATION

Every International Space Station (ISS) managing organization is involved in risk management. The managing organization uses the ISS risk database ISS Risk Management Application (IRMA) to manage and communicate risk data. A characterization of each risk, its likelihood/consequence scoring, and the mitigation tasks are entered into this database. The individual risks are plotted on a risk matrix to provide a visual representation of the relative importance of each risk so that a managing organization and ISS Program management can readily determine where intervention or resources are required. The overall top risks of the ISS Program are captured in the Top Program Risk (TPR) matrix.

The TPR matrix accumulates the current major issues being managed by the ISS Program. TPRs are risks that significantly affect the safety of flight, ISS Program budget, schedule, crew health, integrity of the ISS hardware/software, or mission success. TPRs are risks that require significant ISS Program resources and attention. The TPRs are evaluated at each Program Risk Advisory Board (PRAB) meeting where all top risks are discussed, integrated, and planned and where appropriate resources and attention can be brought to mitigating the risk. The PRAB is held approximately every six weeks.

The ISS Program Manager reviews plans to mitigate the risk and enters the approved abatement plan into the ISS risk database. It is then tracked by the managing organization using IRMA. Resources are assigned

at the PRAB or other Program forums to effectively manage the risk.

The managing organization for a risk continues the abatement process for the TPR with periodic updates. This process continues until ISS Program management accepts or closes the risk by mitigating each issue to an acceptable level through the PRAB process. Either acceptance or closure action is accomplished by the managing organization and documented in the ISS risk database. This risk process is also conducted at the organizational level for its own set of risks.

When the risk has been eliminated or mitigated down to an acceptable level, the risk is formally closed. The managing organization documents this action in the ISS risk database IRMA. The PRAB may also accept any risk. Accepting a risk means that it may not be possible, technically practical, or cost effective, or that the resources required to fully mitigate the risk exceed the program scope. The PRAB is the only authority that can accept a risk.

There are other ISS processes that also capture and document accepted Program risks that are not currently documented in the IRMA. Other safety and mission assurance processes that capture accepted risk include the approval of noncompliance reports (NCRs); the approval of waivers, deviations, and exceptions; and also the approval of critical items documented on the critical items list (CIL). NASA is reviewing these items to determine which should be defined as TPRs for increased visibility.

As a risk management process improvement, the rules for reviewing, closing, and accepting top risks were reassessed.

### STATUS

In general, NASA is reviewing all accepted, mitigated, and closed risks in the safety, quality, and reliability areas to determine where significant risks have been accepted and whether these items should

be reexamined further or should be defined as TPRs and brought into the existing ISS continuous risk management process for increased visibility.

In terms of the ISS management of previously closed risks, the Space Station Program Control Board (SSPCB) has approved a plan for a near-term reassessment and for periodic future reviews of closed top risks.

## FORWARD WORK

ISS will complete its review of CILs, NCRs, and waivers, deviations, and exceptions. The risk contained in these exemptions will be reviewed by the ISS Program at regular intervals. Accepted risks that carry significant consequences will be captured in the ISS risk management process to ensure they are regularly reviewed. As the ISS Program identifies new NCRs, CILs, and waivers, the Program will evaluate those items for incorporation into the risk management process as well.

Additionally, as part of the Certification of Flight Readiness process, all risks will be either closed or accepted and will be presented to the ISS Program Manager prior to the flight at the Launch Package Review or Stage Operation Readiness Review for

approval. These risks include risks that have been previously accepted and that affect the flight in question.

The ISS Program will implement its plan for a near-term reassessment of previously closed top risks. Beyond the existing mission/increment-specific risk reviews, ISS will update its process documentation for clarification to criteria for top risk closure and acceptance plus regular review of closed top risks

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Jan 04 (Complete)	SSPCB-approved plan for regular review of closed top risks
ISS Program	TBD	Complete review of closed top risks
ISS Program	TBD	Update risk management document (SSP 50175)



## **Part 2.2**

### **Formal Observations of the *Columbia* Accident Investigation Board**

*The observations contained in Chapter 10 of the Columbia Accident Investigation Board (CAIB) Report expand on the CAIB recommendations, touching on the critical areas of public safety, crew escape and survival, vehicle aging and maintenance, quality assurance, test equipment, and the need for a professional training program for NASA managers and personnel. NASA is committed to examining these observations and has already made significant progress in determining the appropriate corrective measures.*

*Part 2.2 analyzes the underlying intent of the CAIB observations regarding the Space Shuttle Program for applicability to the ISS Program. Details are provided that demonstrate NASA's intent to take steps to improve our identification and management of risk for crew safety and mission success.*





# **Columbia Accident Investigation Board**

## **Observation 10.1-1**

NASA should develop and implement a public risk acceptability policy for launch and re-entry of space vehicles and unmanned aircraft.

### **BACKGROUND**

The primary intent of this *Columbia* Accident Investigation Board observation was to cover the launch and entry, either from aborted launch/ascent or normal end of mission, of the Space Shuttle. The International Space Station (ISS), however, relies upon other crew and cargo spacecraft that may be subject to policies established regarding risk to the public.

### **ISS PROGRAM IMPLEMENTATION**

The NASA Headquarters Office of Safety and Mission Assurance (HQ/OSMA) has established a risk-policy working group to develop and coordinate the NASA risk acceptance policy for launch and entry of space vehicles, including future NASA vehicles associated with the ISS. This activity is described in greater detail in Volume 1, the Shuttle Return to Flight Plan (ref. Part 2.2, Observation O10.1-1). This working group will define standards, requirements, risk criteria, and a risk management process for all NASA programs to follow.

### **STATUS**

A NASA Procedures and Guidelines (NPG) document is nearing completion that will include the risk acceptance policy.

### **FORWARD WORK**

At the appropriate time in the NPG review cycle, the recommended policies, standards, and requirements will be assessed by the ISS Program for potential impacts and implementation.

### **SCHEDULE**

Responsibility	Due Date	Activity/Deliverable
HQ/OSMA	Mar 04	Complete NPG for NASA programs
ISS/Safety and Mission Assurance	May 04	Complete assessment of new NPG



# Columbia Accident Investigation Board

## Observation 10.1-2 and 10.1-3

**O10.1-2** NASA should develop and implement a plan to mitigate the risk that Shuttle flights pose to the general public.

**O10.1-3** NASA should study the debris recovered from *Columbia* to facilitate realistic estimates of the risk to the public during Orbiter re-entry.

### BACKGROUND

NASA's approach to the risks posed by Space Shuttle flights (which are closely integrated with the International Space Station (ISS) Program) are addressed in Part 2.2 of the Volume I *NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond*. With the exception of the Space Shuttle Orbiter and the descent module of the Russian Soyuz spacecraft, every part of the ISS on-orbit vehicle and its visiting vehicles is designed to ultimately be disposed of within the Earth's atmosphere by a controlled entry. Such entries, if not controlled, present a risk to the general public. The ISS International Partners each control the entries of their respective visiting vehicles; i.e., Rosaviakosmos controls Soyuz and Progress, the European Space Agency (ESA) will control the Automated Transfer Vehicle (ATV), and the Japanese Aerospace Exploration Agency will control the H-II Transfer Vehicle (HTV). NASA's responsibility is the entry of the ISS vehicle itself, although this event will be implemented with Partner assets (ATV or Progress).

NASA trajectory specialists who study ballistics and entry profiles are the same group in the Mission Control Center for the Space Shuttle and the ISS. All data derived from the *Columbia* accident are entered into the same databases used in trajectory analyses.

### ISS PROGRAM IMPLEMENTATION

In May 1996, NASA completed the *Final Tier-2 Environmental Impact Statement for International Space Station*. This document explicitly addresses the ISS end-of-life disposal as part of the verification of the ISS United States On-orbit Segment (USOS) requirement in the USOS Segment Specification SSP 41162, which reads:

#### 3.3.15 "End-of-life decommissioning and disposal

*The Space Station shall allow for safe disposal of the orbital Space Station at the end of its useful life."*

To assure enough total impulse to transfer the ISS from a stable orbit to a guaranteed, targeted ocean impact within one-half orbit, the ISS Program assessed and verified the propulsive capabilities of the Russian segment and of the ESA ATV as being independently capable of delivering the necessary impulse for a safe and controlled de-orbit of the assembly-complete configuration of the ISS.

The non-U.S. components of the ISS visiting vehicle fleet and its boosters are under the control of the International Partners. All ISS visiting cargo vehicles are intentionally de-orbited into unpopulated regions of the ocean. The Soyuz descent module lands in a remote area of Kazakhstan.

NASA has identified six candidate entry zones on the Earth's surface for a large spacecraft in a 51.6-degree orbit with shallow entry angle. These zones are comprised of completely unpopulated ocean entry corridors extending for thousands of kilometers, and wide enough to handle conservative lateral dispersion of debris with high-energy release at altitude. These zones are routinely used by the Russians in their military and human space flight programs, and will be used by the Japanese and European visiting vehicles once they begin flight operations.

Unlike the Shuttle, there are no constraints on ISS that would require entry before all Partners are ready for and committed to the event and all systems prepared. The redundancy and time-to-criticality of the ISS systems allow the ISS Program to plan the optimum time and place for safe entry.

### STATUS

During assembly, the ISS altitude is managed using fault-tolerant reboost systems to provide a minimum of three months of orbital life (usually more) before the potential of atmospheric entry. The ISS hovers above this three-month limit and is allowed to drift close to it just prior to a Shuttle launch, to maximize the cargo lift

capability of the Shuttle fleet. (Following the *Columbia* accident, the ISS was maneuvered to a high altitude with nearly a year of decay time). Following assembly complete, the altitude strategy requires a minimum of one year of orbital lifetime before orbit decay. In addition to this altitude strategy, reserve propellant is maintained to cover an additional year's worth of reboost and nominal propulsive attitude operations. The decay time (and, therefore, the effective propellant margin) can be extended by drag-reduction techniques at the expense of power margin. The ISS Service Module and all visiting vehicles (except the HTV) are capable of reboosting the ISS, providing multiple fault tolerance against random entry, even in the unlikely occurrence of multiple failures of the on-board propulsion system or in one or more groundings of components of the visiting vehicle fleet.

### **Dress Rehearsals**

The *Mir* space station was de-orbited March 23, 2001, into one of the candidate zones for ISS disposal. NASA worked closely with Rosaviakosmos and RSC-Energia Corporation to understand the details of the operation of this record large spacecraft entry, and to gather lessons learned for the ultimate de-orbit of the ISS. U.S. assets were employed to confirm NASA's technical models of the entry debris survivability and spread. In addition, NASA has conducted one planned destructive entry of one of its own large spacecraft—the 17-ton Compton Gamma Ray Observatory—in June 2000, also supported by data gathering with national assets. Contingency plans were prepared for both entries. A similar docu-

ment will be compiled for the ISS a minimum of one year before its planned entry. The debris field of the *Columbia* further validated NASA's debris survivability and spread models, providing a comprehensive data set to corroborate ISS models.

### **FORWARD WORK**

NASA maintains proficiency in its de-orbit operations planning through exercises with the limited number of crewless spacecraft that can be so maneuvered. The Tropical Rainfall Measuring Mission presents NASA's next opportunity for a controlled destructive entry operation, perhaps as early as 2005. In addition, if the new Gamma Ray Large Area Space Telescope is ultimately equipped with a proposed de-orbit module, NASA will also conduct de-orbit operations for that spacecraft sometime before the planned ISS entry.

Over 400 tons of logistics vehicles will be intentionally de-orbited by the International Partners during the ISS Program, before the destruction of the ISS itself. Within the limits of technology-transfer U.S. export controls, NASA will work closely with its Partners to gather experience and lessons learned in planned destructive de-orbits, in preparation for NASA's role in coordinating the final end-of-life de-orbit of the ISS.

### **SCHEDULE**

Ongoing. ISS trajectory specialists maintain a constant surveillance of ISS attitude and altitude and have plans in place to monitor all known entries of large spacecraft.



# **Columbia Accident Investigation Board**

## **Observation 10.2-1**

Future crewed-vehicle requirements should incorporate the knowledge gained from the *Challenger* and *Columbia* accidents in assessing the feasibility of vehicles that could ensure crew survival even if the vehicle is destroyed.

### **BACKGROUND**

Since its inception, the International Space Station (ISS) Program has sought to provide capabilities for crew escape and survival during all flight phases associated with ISS as noted in Section 10.2 of the *Columbia* Accident Investigation Board Report. ISS capabilities to ensure crew survivability are extensive and are derived from lessons learned during all crewed space vehicles to date, including those of our Russian partners. At all times while a crew is on board ISS, they have immediate access to an escape vehicle. This includes visiting Space Shuttle crewmembers (using the Space Shuttle) as well as ISS expedition crewmembers (using the Soyuz). Should all visiting vehicles be temporarily precluded from resupplying ISS, consumables and spares on board can sustain the expedition crew through at least a 45-day “skip cycle,” if not longer. If a portion of the ISS pressurized modules was to be disabled or isolated by an atmospheric leak, fire, or contamination, an orderly retreat to safety can be effected.

### **ISS PROGRAM IMPLEMENTATION**

The majority of near-term efforts to assess and implement this observation are being carried out by the Space Shuttle Program and are described in *NASA’s Implementation Plan for Space Shuttle Return to Flight and Beyond* (ref. Part 2, Observation O10.2-1). NASA’s long-term efforts to develop a new crewed vehicle are being guided by NASA Procedures and Guidelines (NPG) 8705.2, *Human Rating Requirements and Guidelines*, released in July 2003. In addition to NPG 8705.2, the ISS is working with the office charged with development of future crewed vehicles to provide detailed requirements for crew and cargo needs by the ISS

Program. ISS continues to work side-by-side with this office and has established a dedicated interface function.

In parallel, the ISS Program continues to coordinate with its International Partners to maintain the safety of the ISS crews. Nominal activities and contingency capabilities are continually assessed to maximize performance. Though Russia is formally responsible for Soyuz crew safety, NASA provided backup evacuation and medical support during the landing of the Increment 7 crew in Kazakhstan.

### **STATUS**

The status of ongoing crew survivability studies related to Shuttle and future crewed vehicles is reported in Volume 1 of the Return to Flight (RTF) Implementation Plan.

The safety of ISS crew activities is continuously monitored and managed by many methods and forums. ISS personnel are supporting the Shuttle RTF activities. International cooperation on ISS-unique activities is also proceeding.

### **FORWARD WORK**

The ISS Program will exercise continued diligence in crew survivability support activities and will provide assistance to the Shuttle and to future crewed vehicles programs through joint forums, standards and specifications updates, and lessons learned. No specific new actions have been defined.

### **SCHEDULE**

Ongoing.





# Columbia Accident Investigation Board

## Observation 10.4-1

Perform an independently led, bottom-up review of the KSC Quality Planning Requirements Document to address the entire quality assurance program and its administration. This review should include development of a responsive system to add or delete government mandatory inspections.

### BACKGROUND

The International Space Station Program (ISSP) requirements document, SSP 41173, *Space Station Quality Assurance Requirements*, states that critical characteristics derived from drawings, specifications, and Program-accepted risks shall be designated as inspection points that must be verified by Quality Assurance (QA) personnel during hardware fabrication, build-up, test, use, closeout for launch, and maintenance. These requirements are met by inspection points for contractor and NASA inspectors.

In compliance with Program requirements, the Kennedy Space Center (KSC) International Space Station/Payload Processing Safety and Mission Assurance organization established a NASA Quality Planning Requirements Document (QPRD) governing the NASA Government Mandatory Inspection Points (GMIPs) process. The NASA QPRD is approved by the NASA Chief, Safety and Mission Assurance Division, and establishes a minimum set of GMIPs. This permits additions in inspection planning based on changing requirements or negative trends. GMIP deletion is requested and approved via a deviation/waiver process.

The ISS/Payload Processing Directorate contractor, Boeing, with inputs from NASA developed a contractor QPRD that defines their quality mandatory inspection processes. This document is approved by the Boeing KSC Senior Manager, Mission Assurance. This QPRD satisfies Program and contract requirements.

NASA QA, at their discretion, may choose to inspect characteristics that do not require mandatory inspection points. These inspection points are designated as government surveillance inspection points (SIPs). NASA QA applies a SIP stamp to the work authorization document (WAD) steps for which surveillance inspection is desired. NASA SIPs are treated identically to NASA GMIPs during WAD performance.

### ISS PROGRAM IMPLEMENTATION

The ISSP Quality Assurance Office at Johnson Space Center (JSC) will perform an audit/assessment of the NASA-KSC ISSP quality process and technical implementation. This audit/assessment will include an evaluation of the NASA QPRD to determine the effectiveness of GMIP criteria in assuring verification of critical functions and implementation of these criteria. The audit also includes a review of the mandatory inspection process change process and discrepancy identification and closure process.

### STATUS

The NASA QPRD and the contractor QPRD are being updated to require annual reviews. Changes are to be complete by February 2004. Audit/assessment planning and execution are in progress.

### FORWARD WORK

The audit/assessment team will coordinate their activities with the Space Shuttle Program team performing the same assessment on the Shuttle quality process.

### SCHEDULE

Responsibility	Due Date	Activity/Deliverable
NASA KSC	Feb 04	Update NASA QPRD
Boeing KSC	Feb 04	Update Checkout, Assembly, and Payload Processing Services QPRD
NASA ISSP – JSC	Feb 04	Perform audit/assessment
NASA ISSP – JSC	Mar 04	Report out to Space Shuttle Program Control Board from audit/assessment team

Responsibility	Due Date	Activity/Deliverable
NASA KSC	Apr 04	Respond to audit/assessment findings/observations/rec ommendations
NASA KSC	Jul 04	Implementation complete – audit/assessment findings/observations/ recommendations



# Columbia Accident Investigation Board

## Observation 10.4-2

Kennedy Space Center's Quality Assurance programs should be consolidated under one Mission Assurance office, which reports to the Center Director.

### BACKGROUND

In the year 2000, a major reorganization of Kennedy Space Center (KSC) was implemented. As part of this effort, which is known as "KSC 2000," separate Safety and Mission Assurance (SMA) offices were formed in each appropriate directorate at KSC. This was done to provide direct SMA support to each of the directorates, including the International Space Station (ISS) support.

### ISS PROGRAM IMPLEMENTATION

In close coordination with the effort led by the Associate Administrator for Safety and Mission Assurance (AA/SMA) in responding to CAIB Recommendation 7.5-2, KSC has established a Center-level team to assess the KSC SMA organizational structure.

The ISS Program Office at the Johnson Space Center also has recognized the need to strengthen the Quality Assurance role in overseeing the anomaly resolution process. This activity is described in part 2.1, ISS Continuous Improvement Action ISS-12.

### STATUS

A team was formed from each KSC directorate with SMA organizations. KSC's Safety, Health and Independent Assessment Directorate is working with

AA/SMA to determine the optimal organizational structure to support the Space Shuttle, the ISS Program, and other programs at KSC. Based on the results of this review, KSC will consolidate all SMA efforts into a centralized SMA organization reporting to the Center Director.

### SCHEDULE

Responsibility	Due Date	Activity/Deliverable
KSC Safety, Health and Assessment Directorate and AA/SMA	Dec 03 (Complete)	Recommendations to KSC Center Director
KSC Safety, Health and Assessment Directorate and AA/SMA	Jan 04	Initiate SMA reorganization activities
KSC Safety, Health and Assessment Directorate and AA/SMA	May 04	Complete KSC SMA reorganization



# Columbia Accident Investigation Board

## Observation 10.4-3

KSC quality assurance management must work with NASA and perhaps the DOD to develop training programs for its personnel.

### BACKGROUND

The *Columbia* Accident Investigation Board reported most of the training for Quality Engineers, Process Analysts, and Quality Assurance (QA) Specialists was on-the-job training (OJT) rather than formal training. In general, NASA QA personnel supporting the International Space Station (ISS) Program and Space Shuttle payload programs at Kennedy Space Center (KSC) are provided training in conjunction with OJT training and training for specific process and product tasks (e.g., nonconformance reporting, crimping, wire bonding, etc.).

Boeing, the ISS/Payload Processing Directorate contractor, has a mature training program that encompasses all functions by skill for payload processing. The program includes Training Criteria Standards that have the requirements for each major function; i.e., OJT packages, certifications, physicals, and training courses. These data are housed in a Boeing database located on the Boeing Web site. Each major function has a training administrator or coordinator that monitors the training requirements for each particular department. In addition, the Boeing Quality Organization participates in training provided by the local American Quality Society chapter and the annual Florida Governor Sterling Award Seminar that is geared toward Process Excellence and Trending/Analysis.

### ISS PROGRAM IMPLEMENTATION

While NASA and Boeing both plan and conduct training for their quality personnel, it is acknowledged that improvements can and will be made.

The KSC ISS/Payload Processing Directorate and Boeing are conducting internal reviews of their training plans and templates.

The ISS/Payload Processing Directorate will participate with the KSC Shuttle Processing Directorate's benchmarking of the assurance training programs of the Department of Defense (DoD) and the Defense Contract Management Agency (DCMA). Additional training requirements as a

result of this benchmarking will be incorporated into the ISS and Space Shuttle training templates.

### STATUS

A joint KSC-ISS and Space Shuttle Quality Assurance Training Team has been chartered to develop the process and tools for training of new and current QA personnel. Specifically, the team will develop a program that will provide increased instruction in basic Quality skills. DCMA training processes and requirements will be used as an initial model for this program, and required training must be readily available at reasonable cost. The following are examples of classes being considered:

- A Visual Testing course is being developed for certification recognized by the American Society for Nondestructive Testing.
- DCMA QA training courses being considered for NASA Quality training are:
  - Fundamentals of Quality Assurance
  - Measuring Techniques
  - Calibration System Requirements
  - Statistical Sampling
  - Drawings, Dimensions, and Tolerances
  - Specifications and Standards
  - Data Collection and Analysis

### FORWARD WORK

The ISS/Payload Processing Directorate and the KSC Shuttle Processing Directorate will benchmark with the DoD, the DCMA, and QA training organizations. The ISS/Payload Processing Directorate will document and implement a comparable training program.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
KSC ISS/Payload Processing Directorate	Apr 04	Benchmark DoD and DCMA training programs
KSC ISS/Payload Processing Directorate	Apr 04	Develop and document improved training requirements
KSC ISS/Payload Processing Directorate	TBD	Complete personnel training



# Columbia Accident Investigation Board

## Observation 10.4-4

Kennedy Space Center should examine which areas of International Organization for Standardization 9000/9001 truly apply to a 20 year old research and development system like the Space Shuttle.

### BACKGROUND

NASA imposed International Organization for Standardization (ISO) 9000/9001 as Agency Quality Program requirements on NASA programs and projects. ISO 9000/9001 is more of a business management system than a Quality Program that can assure the mission success of aerospace systems.

### ISS PROGRAM IMPLEMENTATION

During the Kennedy Space Center (KSC) Checkout, Assembly and Payload Processing Services (CAPPS) contract competition in 2002, the ISO 9000/9001 standards were examined and it was determined that ISO 9000/9001 required augmentation to ensure a comprehensive quality assurance (QA) program. In compliance with Agency policy, and with the concurrence of the NASA Headquarters Safety and Mission Assurance (SMA) Office and the International Space Station (ISS) SMA, the ISS/Payloads Processing Directorate imposed the following requirements on the CAPPS contract to substantiate a sound QA program:

- Q9001-2000, American National Standards Institute (ANSI)/ISO/American Society for Quality (ASQ)
- AS9100, American National Standard, Quality Management Systems (QMS) – Requirements, and Society of Automotive Engineers (SAE)

- 9000/9001, Quality Systems – Aerospace – Model for Quality Assurance in Design, Development, Production, Installation and Servicing International Organization for Standardization
- SSP 41173, Space Station Quality Assurance Requirements

### STATUS

KSC and the ISS/Payloads Processing Directorate have implemented Agency requirements.

### FORWARD WORK

The ISS Program will participate with the Space Shuttle Program (SSP) and in Agency-wide initiatives in reviewing applicability of ISO processes to the ISS Program. Target dates and schedules will be same as the Space Shuttle Return to Flight (RTF) Implementation Plan.

### SCHEDULE

Responsibility	Due Date	Activity/Deliverable
KSC/ISS Payloads Processing Directorate	Feb 04	Review SSP findings on ISO 9000 (ref. RTF Implementation Plan, Observation O10.4-4)



# Columbia Accident Investigation Board

## Observations 10.5-1, 10.5-2, 10.5-3

**O10.5-1** Quality and Engineering review of work documents for STS-114 should be accomplished using statistical sampling to ensure that a representative sample is evaluated and adequate feedback is communicated to resolve documentation problems.

**O10.5-2** NASA should implement United Space Alliance's suggestions for process improvement, which recommended including a statistical sampling of all future paperwork to identify recurring problems and implement corrective actions.

**O10.5-3** NASA needs an oversight process to statistically sample the work performed and documented by (United Space) Alliance technicians to ensure process control, compliance, and consistency.

### BACKGROUND

Many of the International Space Station (ISS) elements and payloads, processed by Kennedy Space Center (KSC) ISS/Payload Processing Directorate NASA personnel, are one-of-a-kind and are processed one time through KSC. Therefore, contract surveillance strategy is implemented differently from the Shuttle Processing Directorate because much of the work consists of unique, non-repetitive activities.

The ISS/Payload Processing Directorate performs surveillance, which includes oversight and sampling, of contractor activities. The government's surveillance plan is documented in Attachment J-8 of the Checkout, Assembly, and Payload Processing Services (CAPPS) contract and is titled "Checkout, Assembly and Payload Processing Services Performance Surveillance Plan." It describes the government's plan for providing effective and systematic surveillance and reporting of all aspects of CAPPS contract performance.

As stated in the CAPPS performance surveillance plan:

*"Surveillance will be accomplished through continual monitoring and verification of contract performance. Surveillance can be performed in an insight, oversight (first-time, high risk and out-of-family operations) or a combination mode as determined by the government using a risk-based decision process. There are a variety of surveillance tools including, but not limited to, customer feedback, management information systems, metrics, audit/checklist, sampling, analysis, observation or inspection."*

NASA ISS/Payload Processing Directorate Quality Assurance personnel perform surveillance of real-time operations including reviewing the in-process paperwork to assess compliance with requirements. The NASA Process Analysts perform process assessments of paperwork throughout its life cycle to assess compliance with requirements. NASA Quality Engineering also assesses quality paperwork for compliance with requirements. NASA Quality Assurance is also responsible for review and closure of certain categories of flight hardware work documents. Review and approval of payload processing work documents and hardware nonconformances by NASA Engineering helps to ensure the safety, task success, and reliability, operability, and performance of the system. Identified negative performance trends and recurring problems are communicated to the responsible organization's management through the NASA Corrective Action Request System for corrective actions. Any nonconformances involving changes to ISS flight hardware require review and approval by a senior engineering review board.

### ISS PROGRAM IMPLEMENTATION

For ISS cargo processing, the ISS/Payload Processing Directorate is continuing to use the Checkout, Assembly and Payload Processing Services Performance Surveillance Plan while evaluating changes that may impact NASA's surveillance strategy.

NASA conducted a comprehensive engineering and quality review of a representative sample of the STS-107 integrated payloads ground processing activities and work documents. STS-107 was chosen because the ISS ground processing team also processes payloads that fly independent missions on the Orbiter.

An Integrated Boeing Quality/Configuration Management Team was established to assess the STS-114 work documentation. STS-114, also known as ISS flight LF-1, is the next Shuttle mission to the ISS. The STS-114 documentation was sampled using proven statistical sample methods.

In response to the recent transition to a new payload processing contract, KSC performed a complete review of all governing work procedures and nonconformance processes.

## STATUS

The STS-107 review found no instances where technical issues would affect the integrity of the processed payloads; however, instances of noncompliance with documentation processes were noted.

The STS-114 team completed its assessment and is briefing the results to the various teams and management, including recommendations to improve each category of the sample. The team found no instances of technical issues that would affect the integrity of the processed payloads. Instances of noncompliance with documentation processes were noted in this review, as were also noted during the review of the STS-107 documentation.

A review and update of procedures and associated processes governing ISS processing, including work documentation and noncompliance processes, has been completed. Employees are being trained on updated processes, and Mission Processing Teams are being

briefed on the causes and corrective actions being taken on each issue.

## FORWARD WORK

NASA and Boeing Quality will continue to sample and analyze payload work documents for current and future missions. NASA and Boeing Quality will also ensure corrective and preventative action is accomplished for noted discrepancies. Personnel retraining on revised processes is in progress.

## SCHEDULE

Responsibility	Due Date	Activity/Deliverable
KSC ISS/Payload Processing Directorate	Dec 03 (Complete)	Procedure/process updates complete
KSC ISS/Payload Processing Directorate	July 04	Training on updated processes complete
KSC ISS/Payload Processing Directorate	Ongoing	Continue to operate under the "Checkout, Assembly and Payload Processing Services Performance Surveillance Plan"





## **Columbia Accident Investigation Board**

### ***Observations 10.6-1 and 10.6-2***

**O10.6-1** The Space Shuttle Program Office must make every effort to achieve greater stability, consistency, and predictability in Orbiter Major Modification planning, scheduling, and work standards (particularly in the number of modifications). Endless changes create unnecessary turmoil and can adversely impact quality and safety.

**O10.6-2** NASA and United Space Alliance managers must understand workforce and infrastructure requirements, match them against capabilities, and take actions to avoid exceeding thresholds.

The underlying intent of these observations is addressed in Part 1, R6.2-1.



# **Columbia Accident Investigation Board**

## **Observation 10.6-3 and 10.6-4**

**O10.6-3** NASA should continue to work with the U.S. Air Force, particularly in areas of program management that deal with aging systems, service life extension, planning and scheduling, workforce management, training and quality assurance.

**O10.6-4** The Space Shuttle Program Office must determine how it will effectively meet the challenges of inspecting and maintaining an aging Orbiter fleet before lengthening Orbiter Major Maintenance intervals.

### **BACKGROUND**

As a long-lived vehicle with systems subject to an array of preflight and on-orbit usage conditions, the International Space Station (ISS) Program has addressed the topic of aging through its design, verification, operation, and maintenance activities. Experience with the Russian *Mir* space station also proved to be invaluable and directly relevant to ISS performance assurance.

### **ISS PROGRAM IMPLEMENTATION**

Much of the intent and scope of these observations is addressed in Part 2.1, ISS-7 and ISS-8. In addition, the

ISS Program will continue to assess the applicability of the Space Shuttle Program's responses to these same observations with respect to aging.

### **STATUS**

To be supplied.

### **SCHEDULE**

To be supplied.



# **Columbia Accident Investigation Board**

## ***Observation 10.7-1, 10.7-2, 10.7-3, and 10.7-4***

**O10.7-1** Additional and recurring evaluation of corrosion damage should include non-destructive analysis of the potential impacts on structural integrity.

**O10.7-2** Long-term corrosion detection should be a funding priority.

**O10.7-3** Develop non-destructive evaluation inspections to find hidden corrosion.

**O10.7-4** Inspection requirements for corrosion due to environmental exposure should first establish corrosion rates for Orbiter-specific environments, materials, and structural configurations. Consider applying Air Force corrosion prevention programs to the Orbiter.

### **BACKGROUND**

As a long-lived vehicle with fluid systems subject to an array of preflight and on-orbit usage conditions, the International Space Station (ISS) Program continues to address the topic of corrosion through its design, verification, operation, and maintenance activities. As an example of risk mitigation measures already under way, the ISS crew regularly inspects and eliminates the small amounts of moisture that may accumulate on the cabin walls behind structures where air flow is limited. In response to experience with the internal active cooling systems of the on-orbit U.S. Laboratory, additional measures are under way to assure Node 2 performance as its launch preparations continue.

### **ISS PROGRAM IMPLEMENTATION**

ISS continues to assess corrosion prevention to determine whether additional improvements in current ground and on-orbit practices are needed. Insights from expertise outside the ISS Program will be considered.

### **STATUS**

To be supplied.

### **SCHEDULE**

To be supplied.



# **Columbia Accident Investigation Board**

## **Observation 10.8-1, 10.8-2, 10.8-3, and 10.8-4**

**O10.8-1** Teflon (material) and Molybdenum Disulfide (lubricant) should not be used in the carrier panel bolt assembly.

**O10.8-2** Galvanic coupling between aluminum and steel alloys must be mitigated.

**O10.8-3** The use of Room Temperature Vulcanizing 560 and Koropon should be reviewed.

**O10.8-4** Assuring the continued presence of compressive stresses in A-286 bolts should be part of their acceptance and qualification procedures.

### **BACKGROUND**

The International Space Station (ISS) Program reviews the use of materials during the design review process. Material design standards, requirements, and verification processes are in effect for ISS hardware.

### **ISS PROGRAM IMPLEMENTATION**

The ISS Program continues to assess these *Columbia* Accident Investigation Board observations for potential future hazards.

### **STATUS**

To be supplied.

### **SCHEDULE**

To be supplied.



## ***Columbia Accident Investigation Board***

### ***Observation 10.9-1***

NASA should consider a redesign of the system, such as adding a cross-strapping cable, or conduct advanced testing for intermittent failure.

The International Space Station applicability of this observation in terms of pyrotechnic devices is under review.



## **Columbia Accident Investigation Board**

### ***Observation 10.10-1***

NASA should reinstate a safety factor of 1.4 for the Attachment Rings—which invalidates the use of ring serial numbers 16 and 15 in their present state—and replace all deficient material in the Attachment Rings.

The underlying intent of this observation is addressed in Part 2.1, ISS Continuous Improvement Actions 1, 2, 3, 4, 7, and 12. While the International Space Station (ISS) Program does not use this specific hardware, it does manage the design and operational margins of its own systems and components. A variety of methods are used to assure that requirements are satisfied and any

deviations are well understood with corresponding risk mitigation measures. As reported in the cited sections of this document, recent reassessments have studied the adequacy of ISS processes and products related to Program waivers, deviations, exceptions, hazard reports, failure analyses, certification limits, quality assurance, and flight readiness.



# **Columbia Accident Investigation Board**

## **Observation 10.11-1**

Assess NASA and contractor equipment to determine if an upgrade will provide the reliability and accuracy needed to maintain the Shuttle through 2020. Plan an aggressive certification program for replaced items so that new equipment can be put into operation as soon as possible.

### **BACKGROUND**

The International Space Station (ISS)/Payloads Processing Directorate at the Kennedy Space Center (KSC) uses NASA and contractor equipment that is similar in function to that of the Space Shuttle Program. In general, the ISS ground systems and equipment is newer; most of it fewer than seven years old. In addition to certified ground support equipment (GSE), the ISS uses factory equipment (FE) and special test equipment (STE) developed throughout the Program for use at KSC. Select ground equipment at KSC for future ISS missions is still in development.

### **ISS PROGRAM IMPLEMENTATION**

Unlike the Space Shuttle Program, ISS electronic ground systems, equipment, and simulators at KSC are all digital technology. All electronic test equipment and computer hardware/software used for ISS and payloads are updated and maintained in operational condition by the Instrument Library. The digital test equipment meets the accuracy specifications of the hardware processing work documentation, and proper calibration is verified prior to use. An extensive array of state-of-the-art non-destructive evaluation (NDE) equipment exists between the KSC checkout, assembly, and payload processing services contractor and NASA engineering. Additional test equipment for issue troubleshooting is available from KSC institutional services. American Society of Non-destructive Testing certified inspectors are available for test and interpretation. The KSC NDE Working Group shares experience, knowledge, and equipment between the Station and Shuttle Programs. Calibration is planned, tracked, and managed through the Repeatable Maintenance Recall System.

GSE is certified for use, and controls are in place to modify or develop new pieces of equipment. Noncertified FE or STE requires ISS Program Support Equipment Control Board (SECB) approval prior to use. FE is currently being assessed for upgrades and sustaining engineering support. The SECB also approves require-

ments, implementation plans, and support equipment deviations and waivers.

Payload processing checkout systems have planned obsolescence/replacement strategies in the existing budget baseline. KSC monitors flight hardware and software upgrades and modifies respective ground simulators to emulate on-orbit functional performance. Additionally, existing custom-built systems are being phased out and upgraded to commercial-off-the-shelf distributed networks-based hardware and software systems.

### **STATUS**

ISS electronic ground equipment, ground systems, and simulators use digital technology. Obsolescence upgrades and simulator upgrades have been budgeted. ISS maintenance and calibration of existing equipment is managed to ensure readiness for use on flight hardware.

### **FORWARD WORK**

Continue monitoring flight hardware and software modifications for ground system applicability. Execute modifications as required. Replace obsolete equipment as required. Continue development of new ground equipment for future ISS missions.

### **SCHEDULE**

Ongoing.



# **Columbia Accident Investigation Board**

## **Observation 10.12-1**

NASA should implement an Agency-wide strategy for leadership and management training that provides a more consistent and integrated approach to career development. This strategy should identify the management and leadership skills, abilities, and experiences required for each level of advancement. NASA should continue to expand its leadership development partnerships with the Department of Defense and other external organizations.

### **BACKGROUND**

The *Columbia* Accident Investigation Board found that NASA has a wide range of training and education programs to prepare the Agency for roles of increased responsibility, but the timing and strategy for leadership and management development varied widely across NASA.

### **ISS PROGRAM IMPLEMENTATION**

The International Space Station (ISS) Program recognizes the need for an improved career development program for its personnel. While we support programs provided at the Agency and center level, it is recognized that future managers should also be versed in techniques developed elsewhere; i.e., other government agencies and non-governmental entities.

#### **Agency Level**

The NASA Training and Development Division offers a wide curriculum of leadership development programs. The content of the internally sponsored programs is developed around the NASA leadership model, which delineates six leadership competencies at four different levels. The four levels are executive leader, senior leader, manager/supervisor, and influence leader. NASA also develops leadership skills in the workforce by taking advantage of training and development opportunities at the Office of Personnel Management, the Federal Executive Institute, the Brookings Institute, and the Center for Creative Leadership, among other resources. In addition, NASA sponsors leadership development opportunities through academic fellowships in executive leadership and management, as well as through the NASA-wide Leadership Development Plan.

#### **Center Level**

The Johnson Space Center (JSC) created the JSC Leadership Development Program (JSCLDP) (<http://leadership.jsc.nasa.gov/>). The JSCLDP used

the JSC Leadership Model. This model incorporates the views of JSC leaders regarding the characteristics and behaviors that are important for effective leadership at the Center. The inaugural class for the JSCLDP was selected in spring 2002 and will graduate in early 2004. The program is designed as a one- to two-year program to develop JSC leaders. The inaugural class included five ISS Program Office leaders out of the 25 selected into the program.

#### **Program Level**

In concert with the JSCLDP, the ISS Program is developing a program to develop its leaders. The goals of the ISS Professional Development Program are to (1) show the importance of the individual's work or organization in the broader context of the larger agency; (2) instill a sense of "ethos" for the Agency or organization; and (3) establish and communicate strategic goals for the organization. This program is being modeled after Department of Defense professional development programs used by the U.S. Army, U.S. Air Force, and other services. The ISS plan establishes a training program and a shadowing program. The training program consists of training for new employees, existing employees (GS 2–13), Intermediate Professional Development, and ISS Executive Professional Development.

### **STATUS**

NASA, JSC, and ISS professional development programs are being refined on an ongoing basis. Lessons learned from pilot programs are being turned back into improvements that will benefit the ISS Program technically and managerially.

### **FORWARD WORK**

NASA will continue to benchmark and gather data from other government and non-governmental agencies, corporations, and the academic community. Data received to date from the benchmarking and data collection activities will be used to enhance ISS specialty training



and leadership and development opportunities. NASA Headquarters, the NASA centers, and the major development programs, such as ISS, will collaboratively develop recommendations and options for a more consistent and integrated approach to career development.

## **SCHEDULE**

Under review.





## Part 2.3

### Appendix D.a

*Volume II, Appendix D.a, also known as the “Deal Appendix,” augments the Columbia Accident Investigation Board (CAIB) Report and its condensed list of recommendations. This Appendix outlines concerns raised by Brigadier General Duane Deal and others that, if addressed, might prevent a future accident. The 14 recommendations and three observations contained in this Appendix expand and emphasize CAIB Report discussions of quality assurance processes, corrosion detection methods, factor-of-safety concerns, crew survivability, and ground facility security concerns relating to flight hardware management.*

*The ISS Program is addressing each of the recommendations and observations offered in Appendix D.a. Many of these topics have been addressed in our response to the other formal recommendations and observations in Volume I of the CAIB Report and, therefore, our responses refer to the location in the plan where more complete information is found. Although the recommendations and observations are not numbered in Appendix D.a, we have assigned a number to each for tracking purposes.*





# **Columbia Accident Investigation Board**

## ***Recommendation D.a-1***

Perform an independently led, bottom-up review of the Kennedy Space Center Quality Planning Requirements Document to address the entire quality assurance program and its administration. This review should include development of a responsive system to add or delete government mandatory inspections. Suggested Government Mandatory Inspection Point (GMIP) additions should be treated by higher review levels as justifying why they should not be added, versus making the lower levels justify why they should be added. Any GMIPs suggested for removal need concurrence of those in the chain of approval, including responsible engineers.

### **BACKGROUND**

The *Columbia* Accident Investigation Board noted the need for a responsive system for adding or deleting Government Mandatory Inspection Points (GMIPs) and the need for a periodic review of the Quality Planning Requirements Document (QPRD).

In compliance with preexisting International Space Station (ISS) Program requirements, the Kennedy Space Center (KSC) ISS /Payload Processing Safety and Mission Assurance organization established a NASA QPRD that governs the NASA GMIPs process. The NASA QPRD is approved by the NASA Chief, Safety and Mission Assurance Division, and establishes a minimum set of GMIPs. Addition and deletion of GMIPs is defined in the NASA QPRD and can be proposed by anyone. This QPRD permits additions in inspection planning based not only on changing requirements or negative trends, but also on personnel experience, expert judgment, and other factors. GMIP deletion is requested and justified via a deletion/waiver process, as defined in the QPRD. The ISS/Payload Processing Directorate contractor, Boeing, main-

tains a contractor QPRD that defines their Quality mandatory inspection processes and is approved by the Boeing KSC Senior Manager, Mission Assurance.

### **ISS PROGRAM IMPLEMENTATION**

This recommendation is addressed by in Part 2.2, Observation O10.4-1, of this Implementation Plan. In summary, the ISS Program Quality Assurance Office at Johnson Space Center will perform an audit/assessment of the NASA-KSC ISS Program Quality process and technical implementation. This audit/assessment will include an evaluation of the NASA QPRD to determine the effectiveness of GMIP criteria in assuring verification of critical functions and implementation of these criteria. The audit also includes a review of the mandatory inspection process change process and discrepancy identification and closure process.

As additional process improvements, the NASA QPRD and the contractor QPRD processes are being updated to require annual reviews and to document feedback and appeals procedures for change initiators.



# **Columbia Accident Investigation Board**

## ***Recommendation D.a-2***

Kennedy Space Center must develop and institutionalize a responsive bottom-up system to add to or subtract from Government Inspections in the future, starting with an annual Quality Planning Requirements Document review to ensure the program reflects the evolving nature of the Shuttle system and mission flow changes. At a minimum, this process should document and consider equally inputs from engineering, technicians, inspectors, analysts, contractors, and Problem Reporting and Corrective Action to adapt the following year's program.

### **BACKGROUND**

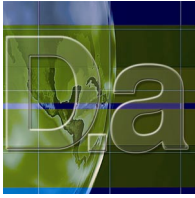
The *Columbia* Accident Investigation Board noted the need for a responsive system for updating Government Mandatory Inspection Points (GMIPs), including the need for a periodic review of the Quality Planning Requirements Document (QPRD).

In compliance with preexisting International Space Station (ISS) Program requirements, the Kennedy Space Center (KSC) ISS /Payload Processing Safety and Mission Assurance organization established a NASA QPRD governing the NASA GMIPs process. The NASA QPRD is approved by the NASA Chief, Safety and Mission Assurance Division, and establishes a minimum set of GMIPs. Addition and deletion of GMIPs is defined in the NASA QPRD and can be proposed by anyone. The ISS/Payload Processing Directorate contractor, Boeing, maintains a contractor QPRD that defines their Quality mandatory inspection processes and is approved by the Boeing KSC Senior Manager, Mission Assurance.

### **ISS PROGRAM IMPLEMENTATION**

This recommendation is addressed in Part 2.2, Observation O10.4-1, of this Implementation Plan. In summary, the ISS Program Quality Assurance Office at Johnson Space Center will perform an audit/assessment of the NASA-KSC ISS Program Quality process and technical implementation. This audit/assessment will include an evaluation of the NASA QPRD to determine the effectiveness of GMIP criteria in assuring verification of critical functions and implementation of these criteria. The audit also includes a review of the mandatory inspection process change process and discrepancy identification and closure process.

As additional process improvements, the NASA QPRD and the contractor QPRD are being updated to require annual reviews and to document feedback and appeals procedures for change initiators.



# **Columbia Accident Investigation Board**

## **Recommendation D.a-3**

NASA Safety and Mission Assurance should establish a process inspection program to provide a valid evaluation of contractor daily operations, while in process, using statistically-driven sampling. Inspections should include all aspects of production, including training records, worker certification, etc., as well as Foreign Object Damage prevention. NASA should also add all process inspection findings to its tracking programs.

### **BACKGROUND**

Many of the International Space Station (ISS) elements and payloads, processed by Kennedy Space Center (KSC) ISS/Payload Processing Directorate NASA personnel, are one-of-a-kind and are processed one time through KSC. Therefore, contract surveillance strategy is implemented differently from the Shuttle Processing Directorate because much of the work consists of unique, non-repetitive activities.

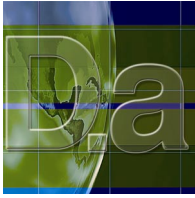
The ISS/Payload Processing Directorate performs surveillance, which includes oversight and sampling, of contractor activities. The government's surveillance plan, documented in Attachment J-8 of the Checkout, Assembly and Payload Processing Services (CAPPS) contract, is titled "Checkout, Assembly and Payload Processing Services Performance Surveillance Plan." It describes the government's plan for providing effective and systematic surveillance and reporting of all aspects of CAPPS contract performance.

### **ISS PROGRAM IMPLEMENTATION**

This recommendation is addressed in the combined response for Observations O10.5-1 through O10.5-3 in Part 2.2 of this Implementation Plan. The foreign object

debris aspects of this recommendation are addressed by R4.2-5 in Part 1 of this Implementation Plan. The status of evaluations of contractor training records and worker certification will be reported in a future edition of this document.

In general, for ISS cargo processing, the ISS/Payload Processing Directorate is continuing to use the "Checkout, Assembly and Payload Processing Services Performance Surveillance Plan" while evaluating changes that may impact NASA's surveillance strategy. In response to the recent transition to a new payload processing contract, KSC performed a complete review of all governing work procedures and nonconformance processes. NASA and Boeing Quality will continue to sample and analyze payload work documents for current and future missions. NASA and Boeing Quality will also ensure corrective and preventative action is accomplished for noted discrepancies. Personnel retraining on revised processes is in progress.



# **Columbia Accident Investigation Board**

## **Recommendation D.a-4**

The Kennedy quality program must emphasize forecasting and filling personnel vacancies with qualified candidates to help reduce overtime and allow inspectors to accomplish their position description requirements (i.e., more than the inspectors performing government inspections only, to include expanding into completing surveillance inspections.)

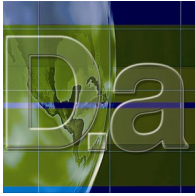
### **BACKGROUND**

The *Columbia* Accident Investigation Board (CAIB) expressed concern regarding staffing levels of Quality Assurance Specialists (QASs) at Kennedy Space Center (KSC). Specifically, they stated that staffing processes must be sufficient to select qualified candidates in a timely manner. KSC has processes, used in the past, for hiring and training QAS personnel including a cooperative (co-op) education program that brings in college students as part of their education process. The co-op program is extensive, including formal classroom and on-the-job training.

### **ISS PROGRAM IMPLEMENTATION**

KSC is currently centralizing the Safety and Mission Assurance workforce to meet the CAIB Report Observation O10.4-2 as reported in Part 2.2 of this Implementation Plan. As a part of that process, workforce staffing requirements, personnel qualifications, and position descriptions will be assessed. In general, hiring practices have improved. As a specific improvement example, KSC has been hiring temporary and term-limited application employees to provide flexibility for short-term staffing issues such as replacements for QAS military reservists who deploy to active duty and instances when permanent hiring authority may not be immediately available.





# **Columbia Accident Investigation Board**

## ***Recommendation D.a-5***

Job qualifications for new quality program hires must spell out criteria for applicants, and must be closely screened to ensure the selected applicants have backgrounds that ensure that NASA can conduct the most professional and thorough inspections possible.

### **BACKGROUND**

The *Columbia* Accident Investigation Board (CAIB) expressed concern regarding staffing qualifications of Quality Assurance Specialists (QASs) at Kennedy Space Center (KSC).

### **ISS PROGRAM IMPLEMENTATION**

NASA, by law, rule, and regulation, must use the qualifications standards published by the U.S. Office of Personnel Management for the GS-1910 Quality Assurance Specialist in assessing the qualification of applicants. In addition, selecting officials identify particular critical selection criteria to assess candidates to ensure they are getting fully qualified individuals.

NASA currently uses two techniques for selecting and developing qualified QASs. First, NASA can hire a QAS at the GS-7, GS-9, or GS-11 level if the candidate

meets a predetermined list of requirements and experience. QAS candidates at all levels require additional training. Candidates selected at lower grades require additional classroom and on-the-job training before being certified as a QAS. Additionally, NASA has a cooperative (co-op) education program that brings in college students as part of their education process. The co-op program is an extensive two-year program, including classroom and on-the-job training.

KSC is currently centralizing the Safety and Mission Assurance workforce to meet another CAIB recommendation. As a part of that process, workforce staffing requirements, personnel qualifications, and position descriptions will be assessed.



# **Columbia Accident Investigation Board**

## **Recommendation D.a-6**

Marshall Space Flight Center should perform an independently-led bottom-up review of the Michoud Quality Planning Requirements Document to address the quality program and its administration. This review should include development of a responsive system to add or delete government mandatory inspections. Suggested Government Mandatory Inspection Point (GMIP) additions should be treated by higher review levels as justifying why they should not be added, versus making the lower levels justify why they should be added. Any GMIPs suggested for removal should need concurrence of those in the chain of approval, including responsible engineers.

### **BACKGROUND**

The *Columbia* Accident Investigation Board noted the need for a responsive system for adding or deleting Government Mandatory Inspection Points (GMIPs), including those at the Michoud Assembly Facility (MAF), and the need for a periodic review of the Quality Planning Requirements Document (QPRD).

In compliance with preexisting International Space Station (ISS) Program requirements, the Kennedy Space Center (KSC) ISS Payload Processing Safety and Mission Assurance organization established a NASA QPRD governing the NASA GMIPs. The QPRD permits additions in inspection planning based not only on changing requirements or negative trends, but also on personnel experience, expert judgment, and other factors. GMIP deletion is requested and justified via a deletion/waiver process, as defined in the QPRD. GMIP changes can be proposed by anyone.

### **ISS PROGRAM IMPLEMENTATION**

This recommendation is addressed by Observation O10.4-1 in Part 2.2, of this Implementation Plan. This response focuses on the implications related to KSC and not the MAF because MAF does not process ISS Program hardware. In summary, the ISS Program Quality Assurance Office at Johnson Space Center will perform an audit/assessment of the NASA-KSC ISS Program Quality process and technical implementation. This audit/assessment will include an evaluation of the NASA QPRD to determine the effectiveness of GMIP criteria in assuring verification of critical functions and implementation of this criteria. The audit also includes a review of the mandatory inspection process change process and discrepancy identification and closure process.

As additional process improvements, the NASA QPRD and the contractor QPRD are being updated to require annual reviews and to document feedback and appeals procedures for change initiators.



# **Columbia Accident Investigation Board**

## **Recommendation D.a-7**

Michoud should develop and institutionalize a responsive bottom-up system to add to or subtract from Government Inspections in the future, starting with an annual Quality Planning Requirements Document review to ensure the program reflects the evolving nature of the Shuttle system and mission flow changes. Defense Contract Management Agency manpower at Michoud should be refined as an outcome of the QPRD review.

### **BACKGROUND**

The *Columbia* Accident Investigation Board noted the need for a responsive system for updating Government Mandatory Inspection Points (GMIPs), including the need for a periodic review of the Quality Planning Requirements Document (QPRD).

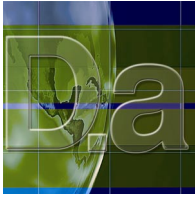
In compliance with preexisting International Space Station (ISS) Program requirements, the Kennedy Space Center (KSC) ISS Payload Processing Safety and Mission Assurance organization established a NASA QPRD governing the NASA GMIPs.

### **ISS PROGRAM IMPLEMENTATION**

This recommendation is addressed by Observation O10.4-1 in Part 2.2 of this Implementation Plan. This

response focuses upon the implications related to KSC and not the Michoud Assembly Facility (MAF) because MAF does not process ISS Program hardware. In summary, the ISS Program Quality Assurance Office at Johnson Space Center will perform an audit/assessment of the NASA-KSC ISS Program Quality process and technical implementation. This audit/assessment will include an evaluation of the NASA QPRD to determine the effectiveness of GMIP criteria in assuring verification of critical functions and implementation of this criteria. The audit also includes a review of the mandatory inspection process change process and discrepancy identification and closure process.

As additional process improvements, the NASA QPRD and the contractor QPRD are being updated to require annual reviews and to document feedback and appeals procedures for change initiators.



# Columbia Accident Investigation Board

## Recommendation D.a-8

Kennedy Space Center should examine which areas of ISO 9000/9001 truly apply to a 20-year-old research and development system like the Space Shuttle.

### BACKGROUND

NASA imposed International Organization for Standardization (ISO) 9000/9001 as Agency Quality Program requirements on NASA programs and projects. ISO 9000/9001 is more of a business management system than a quality program that can assure the mission success of aerospace systems.

### ISS PROGRAM IMPLEMENTATION

This recommendation is addressed in Section 2.2, Observation O10.4-4, of this Implementation Plan. In compliance with Agency policy and with the concurrence of the NASA Headquarters Office of Safety and Mission Assurance and the International Space Station (ISS) Safety and Mission Assurance office, the ISS/Payloads Processing Directorate in 2002 imposed the following requirements on the Checkout, Assembly, and Payload Processing Services contract to substantiate a sound quality assurance program:

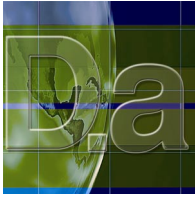
Q9001-2000, American National Standards Institute (ANSI)/ISO/American Society For Quality (ASQ)

AS9100, American National Standard, Quality Management Systems (QMS) – Requirements, and Society of Automotive Engineers (SAE)

9000/9001, Quality Systems – Aerospace – Model for Quality Assurance in Design, Development, Production, Installation, and Servicing International Organization for Standardization

SSP 41173, Space Station Quality Assurance Requirements

The ISS Program will participate with the Space Shuttle Program and Agencywide initiatives in reviewing applicability of ISO processes to the ISS Program.



# **Columbia Accident Investigation Board**

## ***Recommendation D.a-9***

Develop non-destructive evaluation inspections to detect and, as necessary, correct hidden corrosion.

### **BACKGROUND**

The International Space Station (ISS) Program addresses corrosion surveillance through its design and verification processes for prelaunch hardware and through operations and maintenance procedures for on-orbit hardware. For example, the ISS crew regularly inspects and eliminates the small amounts of moisture that may accumulate on the cabin walls behind structures where airflow is limited. Also, in response to experience with the internal active cooling systems of the on-orbit U.S. Laboratory, additional inspections are

under way to assure Node 2 and truss structures conditions as their launch preparations continue.

### **ISS PROGRAM IMPLEMENTATION**

This recommendation is addressed in Section 2.2, Observations O10.7-1 through O10.7-4, of this Implementation Plan. ISS continues to assess corrosion prevention to determine whether additional improvements in current ground and on-orbit practices are needed. Insights from expertise outside the ISS Program will be considered.



# **Columbia Accident Investigation Board**

## ***Recommendation D.a-10***

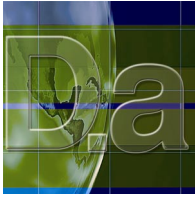
NASA should evaluate a redesign of the Hold-Down Post Cable, such as adding a cross-strapping cable or utilizing a laser initiator, and consider advanced testing to prevent intermittent failure.

### **BACKGROUND**

*NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond* includes a detailed discussion of this issue, which potentially holds meaningful lessons for the International Space Station (ISS) Program, in Section D.a-10.

### **ISS PROGRAM IMPLEMENTATION**

This recommendation will be addressed in Section 2.2, Observation O10.9-1, of this Implementation Plan. The ISS applicability of this observation in terms of pyrotechnic devices and their initiator circuitry is currently under review.



# Columbia Accident Investigation Board

## Recommendation D.a-11

NASA must reinstate a safety factor of 1.4 for the Attach Rings—which invalidates the use of ring serial numbers 15 and 16 in their present state—and replace all deficient material in the Attach Rings.

### BACKGROUND

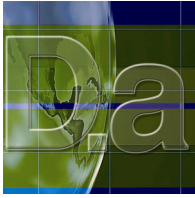
The *Columbia* Accident Investigation Board found that NASA often used analysis when testing would have been more appropriate to determine material properties and safety factors. NASA's use of analysis to determine the adequacy of the tensile strength of the Solid Rocket Booster to External Tank attachment rings on the Space Shuttle was given as an example of a case where subsequent testing determined the factor of safety to be below the requirement threshold of 1.4.

### ISS PROGRAM IMPLEMENTATION

As reported in Section 2.2, Observation O10.10-1, of this Implementation Plan, the underlying intent of this recommendation is addressed in Part 2.1, ISS

Continuous Improvement Actions 1, 2, 3, 4, 7, and 12. While the International Space Station (ISS) Program does not use this specific hardware, it does manage and verify the design and operational margins of the hardware components to ensure that specified safety margins are met.

A variety of methods are used to assure that requirements are satisfied and any deviations are well understood with corresponding risk mitigation measures. As reported in the cited sections of this document, recent reassessments have studied the adequacy of ISS processes and products related to Program waivers, deviations, exceptions, hazard reports, failure analyses, certification limits, quality assurance, and flight readiness.



# **Columbia Accident Investigation Board**

## **Recommendation D.a-12**

To enhance the likelihood of crew survivability, NASA must evaluate the feasibility of improvements to protect the crew cabin on existing Orbiters.

### **BACKGROUND**

The *Columbia* Accident Investigation Board found that in both the *Challenger* and the *Columbia* accidents, the crew cabin initially survived the disintegration of the Orbiter intact. The status of ongoing crew survivability studies related to the Shuttle Program is reported in *NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond*.

### **ISS PROGRAM IMPLEMENTATION**

This recommendation is addressed in Section 2.2, Observation O10.2-1, of this Implementation Plan. Since its inception, the International Space Station (ISS)

Program has sought to provide capabilities for crew escape and survival during all flight phases. ISS capabilities to ensure crew survivability are extensive and are derived from lessons learned during all crewed space vehicles to date, including those of our Russian partners. The ISS Program is a participant in the Crew Survivability Working Group and will continue to make recommendations for protecting the crew in future exploration vehicles as well as evaluating options to enhance crew survivability on the ISS.





# Columbia Accident Investigation Board

## Recommendation D.a-13 and D.a-14

**D.a-13** NASA and ATK Thiokol perform a thorough security assessment of the RSRM segment security, from manufacturing to delivery to Kennedy Space Center, identifying vulnerabilities and identifying remedies for such vulnerabilities.

**D.a-14** NASA and Lockheed Martin complete an assessment of the Michoud Assembly Facility security, focusing on items to eliminate vulnerabilities in its current stance.

### BACKGROUND

During security program assessments at the Reusable Solid Rock Motor facility and the Michoud Assembly Facility, the *Columbia* Accident Investigation Board expressed concerns about several elements of the overall security of flight hardware involving adequacy of staff and surveillance of hardware in storage.

At the Kennedy Space Center (KSC), International Space Station (ISS) flight hardware is processed and stored in secure, controlled areas located in the high bays of the Space Station Processing Facility (SSPF) and the Operations and Checkout (O&C) building. These areas are controlled via a Personal Access Control Accountability System (PACAS) that only allows approved individuals access. Subsequent to the attacks on September 11, 2001, NASA conducted a full security program vulnerability assessment of KSC, including the SSPF and the O&C. Additionally, as a result of Presidential Directive 63, which was recently superseded by Homeland Security Presidential Directive 7, a Minimal Essential Infrastructure (MEI) plan allocated funding to KSC to reinforce its security. Part of this funding was allocated to the SSPF to provide additional security to the ISS flight hardware and equipment located there. These modifications include the installation of a permanent fence to secure a barrier around the high bay that contains ISS flight hardware and additional closed circuit television capability. An enhanced electronic perimeter will be installed between the SSPF office area and the high bay. The perimeter of the high bay will include enhanced alarms at all entry and exit points. Additionally, SSPF second-floor control room areas will be changed from the current cipher lock control to a PACAS as well.

Payload hardware delivered to KSC from non-government customers, such as universities, and hardware delivered for late stowage onto the Space Shuttle are inspected by KSC security personnel as the

hardware enters the KSC gates. A rigorous inspection was conducted on STS-107, including the use of trained canines for selected payloads.

All access routes onto KSC are controlled by armed guards. Each individual wishing to access the Center must possess a valid badge to gain entry. All KSC employees must be permanently badged and are accounted for in a common data system. All domestic customers, suppliers, and partners requiring entry onto the Center must have a valid badge authorized through KSC security and a badged KSC employee sponsor. Credentials for access to KSC do not permit entry into controlled areas containing flight hardware as described above. To obtain the PACAS card required to gain entry into controlled areas, individuals must be in the Personnel Reliability Program (PRP) and have a favorably completed National Agency Check (NAC) to obtain a permanent badge. The NAC includes investigations from Federal and local law enforcement. Those customers, suppliers, and partners requiring access to flight hardware for short durations who do not possess a PRP must be escorted by a badged employee with the proper credentials for that controlled area. For foreign national customers, suppliers, and partners, an NAC is required not only for access to controlled areas described above, but also for entry through the KSC gates. As part of the NAC, KSC security compares each foreign national name against a denied persons list through the Departments of State and Commerce. All ISS and payload customers, suppliers, and partners requiring access to the Space Shuttle and ISS assets in the LC 39 area must be escorted by a badged KSC employee.

### ISS PROGRAM IMPLEMENTATION

As noted in the ISS response to R4.2-3, access to flight hardware closeouts are closely controlled and require the presence of more than one witness. Processing guidelines in use for contractor hardware are being

formulated into a Standard Practice and Procedure that will apply to all ISS Program hardware at KSC.

Current security controls for access to KSC, as well as to the ISS hardware located in the SSPF and the O&C, will continue to be strictly enforced. Facility modifications to the SSPF to support the MEI upgrades are

planned to begin in April 2004. Completion of the modifications is expected in October 2005.

The ISS Program is reassessing its security at other locations, and will discuss results in a future edition of this document.



# **Columbia Accident Investigation Board**

## ***Recommendation D.a-15***

As an outcome of the Quality Program Requirements Document review, manpower refinements may be warranted (for example, should a substantial change in Government Inspections justify additional personnel, adjust the manpower accordingly). While Board recommendations to evaluate quality requirement documents should drive decisions on additional staffing, in the interim, staffing with qualified people to current civil service position allocations should be expedited.

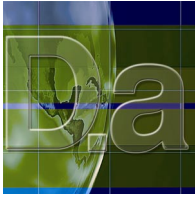
### **BACKGROUND**

The *Columbia* Accident Investigation Board (CAIB) expressed concern regarding staffing levels of Quality Assurance Specialists (QASs) at Kennedy Space Center (KSC).

### **ISS PROGRAM IMPLEMENTATION**

KSC is currently centralizing the Safety and Mission Assurance workforce to meet CAIB Observation

O10.4-2, as discussed in Part 2.2 of this Implementation Plan. As a part of this process, workforce staffing requirements, personnel qualifications, and position descriptions will be assessed and anticipated additional resource requirements will be input to the appropriate annual budget requests. KSC has also been hiring temporary and term-limited appointment employees to provide flexibility for short-term staffing issues such as replacements for QAS military reservists who deploy to active duty and instances when permanent hiring flexibility may not be immediately available.



# **Columbia Accident Investigation Board**

## ***Recommendation D.a-16***

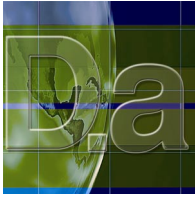
NASA-wide quality assurance management must work with the rest of NASA (and perhaps with the Department of Defense) to develop training programs for its quality program personnel.

### **BACKGROUND**

The *Columbia* Accident Investigation Board reported that most of the training for Quality Engineers, Process Analysts, and Quality Assurance Specialists was on-the-job training (OJT) rather than formal training. In general, NASA Quality Assurance personnel supporting the International Space Station (ISS) Program and the Space Shuttle payload programs at Kennedy Space Center are provided OJT as well as training for specific process and product tasks (e.g., nonconformance reporting, crimping, wire bonding, etc.).

### **ISS PROGRAM IMPLEMENTATION**

The ISS response to this observation is addressed in Section 2.2, Observation O10.4-3, of this Implementation Plan. In summary, a team consisting of engineers and QASs in both the Shuttle and the ISS Programs has been formed to develop and document a more robust training program based on Department of Defense and Defense Contract Management Agency training requirements and to determine where we can directly use their training.



# **Columbia Accident Investigation Board**

## **Recommendation D.a-17**

An evaluation of the disparity of Quality Assurance Specialist civilian grades at Kennedy Space Center compared to other NASA centers should be accomplished to determine whether the current grade levels are appropriate.

### **BACKGROUND**

The *Columbia* Accident Investigation Board (CAIB) expressed concern regarding civilian grade levels for Quality Assurance Specialists (QASs) at the Kennedy Space Center (KSC). Two areas of concern were noted. It was asserted that KSC Mission Assurance Chiefs are at a lower grade than the Chief Engineer or Launch Director. It was further stated that KSC is the only NASA center evaluated that has QAS grades set at GS-11 while other centers have QAS grades set at GS-12. The CAIB Report pointed out that this apparent disparity should be evaluated because it could cause pressure in resolving conflicting priorities between organizations.

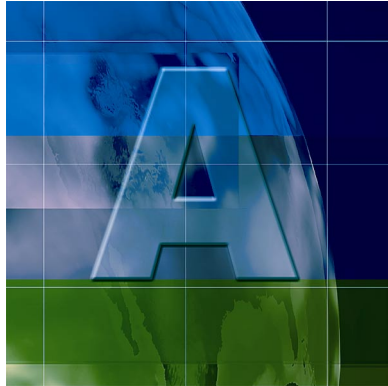
### **ISS PROGRAM IMPLEMENTATION**

In response to this CAIB observation, KSC has reviewed its grade structure for QASs at KSC. GS-1910 is the Office of Personnel Management classification code used for both Shuttle and ISS Program QAS positions

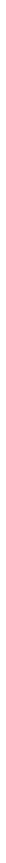
at KSC. A documented comparative study of these journeyman-level QAS positions, functions, and pay grades across all NASA centers has been completed. This study has concluded that KSC is consistent with all NASA centers in grading for positions performing the same type and level of work.

In the International Space Station (ISS) Payloads Processing Directorate, the Mission Assurance Chiefs are at the same grade as the Chief Engineer, Technical Operations Director, and Mission Managers (equivalent to the Shuttle Launch Director). ISS does not have a grade disparity in this area.





## **Appendix A: NASA's ISS Continuing Flight Process**







## BACKGROUND

Reaping the lessons learned from the *Columbia* accident and the *Columbia* Accident Investigation Board's (CAIB's) findings started immediately after the accident. While the CAIB was conducting its investigation, the International Space Station (ISS) Program began an intensive effort to examine its own processes and operations to reduce risk under a continuous improvement initiative. As the CAIB released its preliminary findings, the ISS Program assessed them for applicability. Other continuous activities were derived from the experience the ISS Program has gained from three years of crewed ISS operations and five years of system operation.

Maj. General Michael C. Kostelnik, USAF, Retired, Deputy Associate Administrator for ISS and Space Shuttle Programs, charted the Continuing Flight Team (CFT) under the leadership of Mr. Albert D. Sofge. The CFT will review the output of the CAIB Report and determine the areas that are applicable to the ISS Program and ensure there are actions in place addressing those outputs.

## CONTINUING FLIGHT TEAM DUTIES

The CFT will:

- Assess the CAIB Report for applicability to the ISS Program.
- Review ISS Program posture with respect to the applicability to the Report.
- Ensure ISS Program actions are in place to address applicable areas of the Report.
- Document ISS Program progress in addressing these actions.

## CONTINUING FLIGHT TEAM PROCESS

The CFT will review the CAIB Report and will work in concert with the ISS Program to develop alternative options and proposals for the DAA, the ISS and Space Shuttle Programs, and the Space Flight Leadership Council (SFLC), as required, for addressing change requirements. The ISS Program Manager or Space Shuttle Program Manager will implement the approved change requirements, as appropriate.

The CFT will use existing ISS Program boards and panels as required to provide information and analysis. The ISS Program will provide administrative support, including action tracking, to the CFT. The CFT Lead and the ISS Program Manager will work closely to ensure full coordination of the CFT efforts across the Program elements.

## SPACE FLIGHT LEADERSHIP COUNCIL

Cochaired by the Associate Administrator for Space Flight and the Associate Deputy Administrator for Technical Programs, the SFLC will provide guidance resulting from insights into ISS and Space Shuttle operations, and mission requirements. The SFLC may also direct independent analysis on technical issues related to CFT issues. The membership of the SFLC includes the Office of Space Flight Center Directors (Johnson Space Center, Kennedy Space Center, Marshall Space Flight Center, and Stennis Space Center) and the Associate Administrator for Safety and Mission Assurance. SFLC meetings are scheduled as needed.





## **Appendix B: ISS Continuing Flight Team Charter Letter**





Reply to Attn of:

M-1

September 8, 2003

TO: Johnson Space Center  
Attn: OA/International Space Station (ISS) Program Manager

FROM: M-1/Deputy Associate Administrator International Space Station and  
Space Shuttle Program

SUBJECT: ISS Continuing Flight Team (CFT)

Administrator O'Keefe and the Agency have embraced the Columbia Accident Investigation Board (CAIB) report as a document that is applicable to all human space flight endeavors. Our response to the CAIB recommendations, "*NASA's Implementation Plan for Return to Flight and Beyond*", addresses the recommendations from primarily a Space Shuttle program perspective. During the timeframe prior to the publication of the CAIB report as the CAIB made public their preliminary recommendations, the ISS program also considered these and began factoring the intent into the ongoing execution of the Program as applicable. The ISS program has implemented several changes. With this letter I am chartering the CFT to formally assess and act upon the CAIB recommendations, observations, and findings as they apply to ISS and determine required additional changes.

The Space Flight Leadership Council will review the CFT proposed changes as required. Upon approval by the Space Flight Leadership Council, the ISS Program Manager will implement these changes. The CFT can also make recommendations for studies of long-term changes that will offer the possibility to bolster flight safety and operational resilience for the remaining life of the ISS.

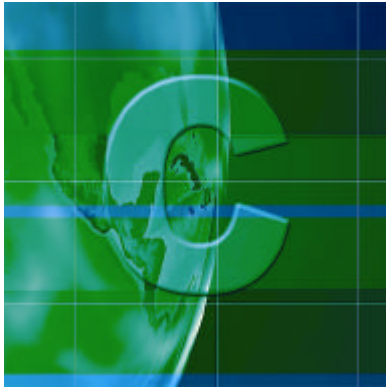
Mr. Albert Sofge will lead the CFT. He will submit a plan outlining the team composition and concept of operations by September 19, 2003. To ensure coordination and efficient implementation of changes, the ISS program will have a significant role in the process.

The ISS Program Manager, Mr. William Gerstenmaier, retains full authority over and responsibility for management of the ISS. Mr. Gerstenmaier will work closely with Mr. Sofge to ensure coordination of CFT recommendations into the overall management of the ISS.

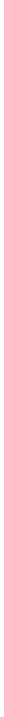
A handwritten signature in black ink, appearing to read "Michael C. Kostelnik", with a long, sweeping horizontal line extending to the right.

Michael C. Kostelnik





## **Appendix C: Continuing Flight Team Priorities**







National Aeronautics and  
Space Administration

**Lyndon B. Johnson Space Center**  
2101 NASA Road 1  
Houston, Texas 77058-3696



December 18, 2003

Reply to Attn of: OX-03-009

TO: Distribution

FROM: OA/Manager, International Space Station Program

SUBJECT: Continuing Flight Team (CFT)

Our entire NASA family was affected by the tragic loss of the Space Shuttle Columbia and its crew. For the International Space Station (ISS) Program, our strategy during this difficult period is to address the Columbia Accident Investigation Board's (CAIB) report on three fronts: an unwavering commitment to learn from this tragedy; to reshape the ISS Program based on those lessons; and to carry out the NASA Administrator's directive to continue our mission of building and operating the ISS as effectively and safely as possible.

The CAIB report identifies many areas for improvement within NASA including systemic issues that directly or indirectly affect the way we plan, develop and operate. The Deputy Associate Administrator (DAA) for ISS and Space Shuttle Programs, Major General Michael Kostelnik, chartered CFT to insure that actions are in place to address CAIB outputs that are applicable to ISS. In late October, the CFT published its initial response to the CAIB report. Entitled "NASA's Implementation Plan for ISS Continuing Flight," it embraced the CAIB report and explained what the ISS Program is doing to address each applicable CAIB recommendation. It also included a comprehensive set of self-initiated corrective actions and process improvements as ISS Continuous Improvement actions. The Implementation Plan will be periodically updated as our analyses and reassessments mature and to include the additional CAIB outputs. The target date for Revision 1 release is mid-December to early January.

The ISS strategy for continuing flight will examine and improve the following three key areas: technical (designs, analyses, and processes); management (roles, responsibilities, and decision-making); organizational structure and other matters (culture, attitudes, and mindset). Each applicable output or NASA-identified process improvement must have a specific plan for corrective action and implementation. Critical safety-of-flight issue identification and resolution is our highest priority. Within the framework of this commitment, we are reminded that our mission is, above all else, to keep the ISS crew safe and the Station operating in a safe manner. We must ensure that nothing dilutes our efforts in that regard.

With this in mind, I have created a core team of ISS personnel to work with the CFT to update the ISS CFT Plan in an efficiently managed process consistent with our ongoing responsibilities. This core team will be led by Mr. Gordon Ducote in the External Relations Office and supported by specific individuals in the ISS organization whose specialties are key

to responding to and implementing these efforts, including vehicle engineering, safety, program and mission integration. We will have an on-going effort to work on all of the applicable CAIB outputs and Continuous Improvement areas but establishing priorities on select tasks is warranted. Our priorities and the key leads are:

1. Process improvements in key major reviews, (e.g. Certification of Flight Readiness) to ensure that all issues are identified and addressed by management (key lead: W. Rod Jones)
2. Assessing the validity of our software models to accurately characterize the risk environment and the threats to mission safety and success (key lead: Carol Rush)
3. Improve our ability to identify, track, analyze, and mitigate in-flight anomalies (key lead: Kevin Meehan)
4. Identify improved methods of tracking anomaly data for performance trending (key lead: Phillip Dempsey)
5. Develop improved methods for documenting operational constraints including the associated waiver/deviation process with emphasis on the Medical Operations Requirement Document and the Generic Groundrules Requirements and Constraints Document (key lead: Kathy Leary)

In addition, other process and technical improvements will continue to require our attention and key individuals will be named to support these tasks.

The ISS Program's part in the Space Shuttle return to flight and the ISS continuing to fly effort requires us to identify, understand, mitigate, and control risk while accomplishing the mission entrusted to us. The crew of STS-107 was dedicated to the vision of science and exploration and devoted their lives to further it. It is our job to continue their vision.



William H. Gerstenmaier

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